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(57) Abstract

Screening of compounds for activity toward inhibition of prostate cancer cell proliferation is provided. A cell line is employed which can be used in conventional equipment for determining activity of compounds, where the cell line uses a marker whose expression is responsive to therapeutically active compounds.

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PROSTATE CANCER DRUG SCREENING

TECHNICAL FIELD

The present invention relates to screening methods for identifying compounds useful in the treatment of prostate cancer.

BACKGROUND

Prostate cancer is the fastest growing neoplasm in men with an estimated 244,000 new cases in the United States being diagnosed in 1995, of which approximately 44,000 deaths will result. Hormonal ablation therapy, either surgically or chemically with anti-androgens, is the main stay of treatment for advanced carcinoma of the prostate. However, androgen ablation therapy failed within 12-18 months with the disease becoming androgen independent. Following the failure of androgen therapy, the median patient survival time is eight months. Other approaches to treating prostate cancer -- external radiation, radioactive seed therapy, cryotherapy, etc.-- are directed toward organ confined disease of the prostate and are unable to treat metastatic tumors.

The prostate-specific antigen (PSA), a member of the human kallikrein gene family, is a Mr = 34,000 chymotrypsin like protein that is synthesized exclusively by normal, hyperplastic, and malignant prostatic epithelia. Hence, the PSA's tissue-specific relationship has made it an excellent biomarker for identifying benign prostatic hyperplasia (BPH) and prostatic carcinoma (CaP), hereinafter CaP. Normal serum levels of PSA in blood are typically below 5 ng/ml, with elevated levels indicative of BPH or CaP. Serum levels of 200 ng/ml have been measured in end-stage metastatic CaP.

Another member of the kallikrein gene family, human glandular kallikrein-1 (*hGK-1* or *hKLK2*, encoding the hK2 protein), shares a number of characteristics with PSA. First, both are expressed exclusively in the prostate and are up-regulated by androgens primarily by

transcriptional activation. Wolf et al. (1992) *Molec. Endocrinol.* 6:753-762. Morris (1989) *Clin. Exp. Pharm. Physiol.* 16:345-351; Qui et al. (1990) *J. Urol.* 144:1550-1556; Young et al. (1992) *Biochem.* 31:818-824. Second, *hKLK2* and *PSA* mRNAs are synthesized and co-localize only in prostatic epithelia. Third, *hKLK2* and *PSA* exhibit a high degree of amino acid sequence identity. Schedlich et al. (1987) *DNA* 6:429-437. Fourth, they have similar regulatory elements. There is approximately 80% nucleotide sequence identity between *PSA* and *hKLK2* in the 5'-flanking region from -300 to -1 relative to the transcription initiation site. Young et al. (1992) *Biochem.* 31:818-824. Each promoter contains an androgen responsive element (ARE); their respective ARE's differ from one another by only 1 nucleotide. Schedlich et al. (1987) *DNA* 6:429-437; Murtha et al. (1993) *Biochem.* 32:6459-6464.

The levels of hK2 found in various tumors and in the serum of patients with prostate cancer differ substantially from those of PSA. Circulating hK2 in different relative proportions to PSA has been detected in the serum of patients with prostate cancer. Charlesworth et al. (1997) *Urology* 49:487-493. Expression of hK2 has been detected in each of 257 radical prostatectomy specimens analyzed. Darson et al. (1997) *Urology* 49:857-862. The intensity and extent of hK2 expression, detected using specific antibodies, increased from benign epithelium to high-grade prostatic intraepithelial neoplasia (PIN) and adenocarcinoma, whereas PSA and prostate acid phosphatase (PAP) displayed an inverse pattern of immunoreactivity. Darson et al. (1997) *Urology* 49:857-862. Indeed, it has been reported that a certain percentage of PSA-negative tumors have detectable hK2. Tremblay et al. (1997) *Am. J. Pathol.* 150:455-459.

As mentioned above, both *PSA* and *hKLK2* genes are up-regulated by androgens primarily by transcriptional activation. Androgen induction of gene expression requires the presence of an androgen receptor (AR). Typically, an androgen diffuses passively into the cell where it binds AR. The androgen-activated AR binds to specific DNA sequences called androgen-responsive elements (AREs or ARE sites). Once anchored to an ARE, the AR is able to regulate transcriptional activity in either a positive or negative fashion. Lindzey et al. (1994) *Vitamins and Hormones* 49: 383-432.

The AR belongs to a nuclear receptor superfamily whose members are believed to function primarily as transcription factors that regulate gene activity through binding to specific DNA sequences, hormone-responsive elements. Carson-Jurica et al. (1990) *Endocr. Rev.* 11: 201-220. This family includes the other steroid hormone receptors as well as the thyroid hormone, the retinoic acid and the vitamin D_3 receptors. The progesterone and glucocorticoid receptor are structurally most closely related to the AR. Tilley et al. (1989) *Proc. Natl. Acad. Sci. USA* 86: 327-331; Zhou et al. (1994) *Recent Prog. Horm. Res.* 49: 249-274; and Lindzey et al. (1994) *Vit. Horm.* 49: 383-432.

The AR gene itself is a target of androgenic regulation. In the prostate cancer cells lines PC3 and DU145, which do not express an endogenous AR, androgenic up-regulation of AR cDNA expression occurred in the transfected cells. Dai et al. (1996). Androgenic up-regulation of AR mRNA and protein was observed in PC3 cells that were stably transfected with the AR cDNA, suggesting that AR mRNA regulation also occurs when the cDNA is organized into chromatin. Dai et al. (1996).

The characterization of genes whose expression is limited to the prostate allows the development of screening methods which can identify substances capable of specifically altering the expression of prostate-specific genes.

In the last few years, numerous techniques have been developed for producing vast arrays of potential drug-like compounds. These compounds include not only oligomers, such as oligopeptides and oligonucleotides, but also synthetic organic compounds based on various core structures. In addition, various natural sources have been screened for active compounds, such as those found in jungles, the ocean and the like. Thus, there is a great proliferation of available compounds for screening for physiological activity.

The process of identifying prospective compounds having therapeutic activity is primarily held back by the absence of useful screening assays. In order for a screening assay to be useful, it should be capable of automation, allow for the screening of large numbers of samples without requiring extensive equipment or housing, be relatively inexpensive, and provide for a clear indication of activity. There is, therefore, substantial interest in identifying

new screening assays which would allow for the screening of compounds which may have therapeutic activity in relation to prostate cancer.

SUMMARY OF THE INVENTION

Methods and compositions are provided for screening therapeutic agents for the treatment of prostate cancer. The methods employ a PSA expressing stably transformed epithelial cell line comprising a construct of the PSA gene enhancer/promoter and a marker gene, e.g. luciferase. The cells are shown to be responsive to the addition of androgen agonists and antagonists by the modified expression of the marker gene. The methods also employ a cell line derived from the prostate, which cell line is stably transformed with a construct comprising a transcriptional control region of a gene, such as PSA or *hKLK2*, whose expression is substantially limited to cells of the prostate, and a reporter gene. Alterations in the levels of reporter gene product in the presence of a candidate agent or compound are indicative of a potential therapeutic agent.

Accordingly, in one aspect, the invention includes a method for screening drugs for the treatment of prostate cancer employing PSA expressing cells comprising an expression construct which comprises a transcriptional initiation region of the prostate specific antigen enhancer and a promoter and a gene whose expression product provides a detectable signal, wherein said gene is under the transcriptional control of said transcriptional initiation region, said method comprising combining said PSA expressing cells with a candidate drug in the presence of an androgen for sufficient time for detectable expression of said gene, and detecting the level of expression of said gene as compared to the level of expression in the absence of said candidate drug.

In another aspect, the invention provides a method A method for screening drugs for the treatment of prostate cancer employing PSA expressing cells comprising an expression construct which comprises a transcriptional initiation region of the prostate specific antigen enhancer and a promoter and a gene encoding an enzyme which catalyzes a reaction resulting, in a detectable signal, wherein said gene is under the transcriptional control of said transcriptional initiation region, said method comprising combining said PSA expressing cells

with a candidate drug in the presence of methyl trienolone or dihydrotestosterone for sufficient time for detectable expression of said enzyme, lysing said PSA expressing cells to provide a lysate and adding the substrate of said enzyme to said lysate, and detecting the level of expression of said enzyme as compared to the level of expression in the absence of said candidate drug.

In another aspect, the invention provides a method for screening compounds for the treatment of prostate cancer employing mammalian cells comprising an expression construct, said expression construct comprising an enhancer of a prostate-specific gene and a promoter and a reporter gene whose expression product provides a detectable signal, wherein said reporter gene is under the transcriptional control of said enhancer, said method comprising the steps of combining said cells with a candidate compound for a sufficient time for detectable expression of said reporter gene, and detecting the level of expression of said reporter gene as compared to the level of expression in the absence of said candidate compound.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a bar graph of anti-androgen induction/inhibition on luciferase expression by the cell line CN1013, Figure 1A indicating induction by hydroxyflutamide, and Figure 1B by cyproterone acetate, before (white bars) and after (dark bars) induction with 1 nM R1881.

Figure 2 is a schematic representation of the hK2 promoter/enhancer region (SEQ ID NO:1). The hatched bar represents the promoter region (Schedlich et al. (1987); GenBank accession number M18156); the dotted portion (including the solid portion) represents an enhancer region; the solid portion represents a smaller region with enhancer activity; and the transcription initiation site is indicated by a bent arrow.

Figures 3A and 3B are bar graphs of testosterone analog R1881 induction of *hKLK2* promoter/enhancer-driven luciferase expression in LNCaP (human metastatic prostate adenocarcinoma) cells. LNCaP cells were transfected with reporter gene constructs, incubated in the presence or absence of inducer, and, 48 hours after transfection, luciferase activity was measured. Figure 3A shows induction, expressed in relative light units (RLU) per μg total protein, of luciferase expression by the *hKLK2* promoter-containing construct CN299

(stippled bars) or by the *hKLK2* promoter/enhancer-containing construct CN322 (solid bars) in the presence of 0 nM or 0.5 nM R1881. Figure 3B shows the fold induction calculated by comparing CN322 RLU/μg protein with CN299 RLU/μg protein in the presence of 0.5 nM R1881.

Figures 4A and 4B are bar graphs of the concentration dependence of R1881-mediated induction of *hKLK2* promoter/enhancer-driven luciferase expression. LNCaP cells were transfected with CN322 and cells were incubated in various concentrations of R1881. Cells were harvested 48 hours after transfection and luciferase activity was measured. Figure 4A shows luciferase activity, expressed as RLU/μg protein, from cultures incubated in the presence of 0, 0.01, 0.1, 1, or 10 nM R1881. Figure 4B shows fold induction calculated by comparing RLU/μg protein at a given concentration to RLU/μg protein at 0 nM R1881.

Figure 5 is a bar graph showing induction of luciferase activity as a function of time of incubation with R1881. LNCaP cells were transfected with CN322 and cells were incubated in medium containing 0.5 nM R1881 for various periods of time, after which luciferase activity was measured.

Figure 6 is a bar graph depicting the cell type specificity of *hKLK2* promoter/enhancer-driven luciferase expression. LNCaP or 293 (human embryonal kidney) cells were transfected with CN299 or with CN322 plasmid constructs and incubated in the absence or the presence of 1 nM R1881. Cells were harvested 48 hours post transfection and luciferase activity was measured. Fold induction was calculated by comparing RLU/μg protein with and without 1 nM R1881.

Figure 7 is a bar graph depicting the activity of the *hKLK2* enhancer/promoter in various cell lines. Various cell lines were transfected with either CN322 or CN355, and, after an overnight incubation in complete medium, were incubated in the presence or absence of R1881. CN355 contains a 3.8 kb fragment from approximately -6200 to approximately -2400 of the *hKLK2* enhancer fused to the minimal *hKLK2* promoter to control luciferase expression. The cell lines used were: OVCAR, human ovarian adenocarcinoma; 293, transformed human primary embryonal kidney; PC3, human grade IV prostate adenocarcinoma; LNCaP, metastatic human prostate adenocarcinoma.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Methods are provided for screening compounds for therapeutic effect against prostate cancer. The methods comprise adding the compound in an appropriate medium to PSA producing cells into which has been stably introduced a genetic construct comprising the enhancer/promoter of the prostate-specific antigen (PSA) with a structural gene under the transcriptional regulation of the PSA enhancer/promoter.

Alternatively, the methods comprise adding the compound in an appropriate medium to cells, preferably derived from the prostate, into which has been stably introduced a genetic construct comprising a transcriptional control region of a prostate-specific gene with a structural gene under the transcriptional regulation of the prostate-specific gene transcriptional control region, which structural gene provides for a detectable, quantifiable signal. Examples of prostate-specific genes include, but are not limited to, PSA and *hKLK2*. By measuring the effect of the candidate compound on the level of signal observed as compared to a basal level, one can evaluate the potential of the compound as a therapeutic agent for the treatment of prostate cancer. Particularly, anti-androgenic activity can be evaluated as indicative of therapeutic effects for prostate cancer, although any compound which modifies the expression of a prostate-specific gene, whatever its mode of action, may be considered a candidate compound.

Cells which are suitable for use in the screening methods of the present invention are mammalian cells in which at least one prostate-specific gene is expressed in the cells. Preferably, the cells are prostate cells, more preferably expressing endogenous androgen receptor, even more preferably prostate epithelial cells expressing endogenous androgen receptor. Preferably, the cells employed display expression of the prostate-specific gene whose transcriptional control region, in whole or in part, is contained within the construct used to stably transform the cells. Alternatively, the cells need not be derived from the prostate as long as the normal function of the transcription regulatory elements of the prostate-specific gene is maintained. This may be achieved, for example, by co-transfecting the cell with a gene encoding a product necessary for the normal function of the promoter/enhancer region of

the prostate-specific gene. For example, if the promoter/enhancer region of the prostate-specific gene is inducible by androgen, it may be necessary to co-transfect into the cells a construct which encodes and allows expression of a gene encoding an androgen receptor.

"Androgen receptor" as used herein refers to a protein whose function is to specifically bind to androgen and, as a consequence of the specific binding, recognize and bind to an androgen response element (ARE), following which the AR is capable of regulating transcriptional activity. The AR is a nuclear receptor that, when activated, binds to cellular androgen-responsive element(s). In normal cells the AR is activated by androgen, but in non-normal cells (including malignant cells) the AR may be activated by non-androgenic agents, including hormones. Encompassed in the term "androgen receptor" are mutant forms of an androgen receptor, as long as the function is sufficiently preserved. Mutants include androgen receptors with amino acid additions, insertions, truncations and deletions, as long as the function is sufficiently preserved.

The term "prostate-specific gene" as used herein indicates a gene whose expression is substantially limited to cells of the prostate, in particular to prostate epithelial cells, and whose expression is substantially undetectable in normal cells derived from tissues other than the prostate.

The term "transcriptional control region" as used herein encompasses enhancers, promoter elements and/or any other nucleotide sequence which controls the level of transcription of a coding region.

The prostate-specific gene whose transcription control region is operably linked with a reporter gene may or may not be one whose expression in prostate cells or cell derived from the prostate is inducible, but preferably is inducible. The term "inducible gene" is used herein to indicate a gene which is normally transcriptionally silent in prostate cells or whose expression is substantially undetectable, and whose expression, in the presence of an appropriate inducing agent, is increased at least 10-fold, more preferably at least about 10- to about 50- fold, even more preferably about 50- to about 200-fold, relative to expression in the absence of the inducing agent.

An inducing agent can be any compound which is added to the growth environment of the cell and which, upon contact with and/or entry into the cell, results in the expression of a specific gene or set of genes. For the purposes of the present invention, an "appropriate inducing agent" is one which specifically induces the expression of a gene which is operably linked to a reporter gene. For example, both PSA and *hKLK2* enhancers are inducible with androgen. An example of an inducing agent used is R1881, a testosterone analog.

In one embodiment, the cells which are employed in the screening are stable prostate cancer cell lines which express PSA, particularly based on the LNCaP cell line, which are cells derived from a metastatic tumor isolated from a lymph node. This cell line has been established for an extended period of time, stably maintains expression of PSA, and is readily grown in conventional media.

In this embodiment, the subject cells are produced by introducing an expression construct into a stable prostate cancer cell line expressing PSA at least a level of 10 to 20 ng/mL per 10^6 cells per day. The expression construct comprises as the transcriptional initiation regulatory region, the PSA enhancer with the PSA promoter or a different promoter region, usually the PSA promoter. The 5' non-coding region of the PSA gene may include the region from 0 (the site of transcription initiation) to -6000 or may be truncated, to provide only those sequences essential for the enhancer region and the promoter region. Thus, the particular regions include the enhancer active sequences between -5824 and -3738 with the promoter active region, for the PSA gene, the region from about -560 to +7.

In another embodiment, the cells employed are mammalian cells (preferably prostate cells, even more preferably LNCaP cells) and the expression construct comprises, as the transcriptional initiation regulatory region, an hK2 enhancer with a promoter which may be an *hKLK2* promoter or a heterologous promoter. The 5' non-coding region of the *hKLK2* gene may include the region from +33 (relative to the site of transcription initiation) to -12,014 or may be truncated to provide only those sequences essential for enhancer function and/or promoter function. Particular regions include an approximately 1.7 kb enhancer active fragment from -5155 to -3387 relative to the transcription start site (nucleotides 6859 to 8627 of SEQ ID NO:1), with the promoter active region being the region from about -600 to about

+33 relative to the transcription start site (from about 11420 to 12047 of SEQ ID NO:1). The DNA sequence as such can vary in length and/or nucleotide sequence as long as the requisite function is maintained.

This transcription initiation regulatory region may then be joined to a marker gene which provides for a detectable, desirably quantifiable, signal. Of particular interest are genes which provide for luminescence, such as luciferase, aequorian, β-galactosidase, chloramphenicol acetyl transferase, etc. In addition, one may provide for a marker for selection comprising a constitutive transcriptional initiation region and an antibiotic resistance gene, e.g. neo. In this way, one may select for those cells which have the expression construct stably integrated.

Marker genes, or reporter genes, which may be employed are known to those skilled in the art and include, but are not limited to, luciferase; aequorian (i.e., green fluorescent protein from *Aequorea victoria*); β-galactosidase;, chloramphenicol acetyl transferase; immunologically detectable protein "tags" such as human growth hormone; and the like. See, for example, Current Protocols in Molecular Biology (F.M. Ausubel et al., eds., 1987) and periodic updates. Any assay which detects a product of the reporter gene, either by directly detecting the protein encoded by the reporter gene or by detecting an enzymatic product of a reporter gene-encoded enzyme, is suitable for use in the present invention. Assays include colorimetric, fluorimetric, or luminescent assays or even, in the case of protein tags, radioimmunoassays or other immunological assays. Many of these assays are commercially available.

The construct may be prepared in accordance with conventional ways, introducing each of the components of the construct into a plasmid by employing convenient restriction sites, PCR (polymerase chain reaction) to introduce specific sequences at the termini, which may include providing for restriction sites, and the like. After the expression construct has been prepared, it may be introduced into the cells by any convenient means.

Methods for introducing the expression construct into the cells or cell lines include transfection, complexing with cationic compounds, lipofection, electroporation, and the like. The cells may be expanded and then screened for the presence of the expression construct.

Where an antibiotic resistance gene has been introduced, the cells may be selected for antibiotic resistance and the antibiotic resistance cells then screened for luminescence under appropriate conditions. In the absence of the antibiotic resistance, the cells may be directly screened for luminescence. Conveniently, the assay for luminescence is performed on a lysate using conventional reagents.

After selecting clones which demonstrate high levels of luciferase activity when activated, the induction ratio may be further enhanced by performing limiting dilution with the cells and screening the resulting clones. In this manner, the induction may be at least 20 fold when induced with an inducing agent such as 0.1 - 1.0 nM R1881, preferably at least about 50 fold, and more preferably at least about 100 fold. Usually, the induction will not exceed about 500 fold.

When the prostate-specific gene used to transform the cell is hormone-inducible, cells are desirably grown in hormone-free medium, *e.g.* RPMI medium supplemented with 10% fetal bovine serum, 100 units/ml penicillin and 100 µg/ml streptomycin, and assayed in hormone spiked medium, e.g. 10% strip-serum RPMI with hormone. Desirably, the cells should not have been passaged more than about 50 times, more desirably not more than about 25 times.

The luminescence may be determined in accordance with conventional commercial kits, e.g. enhanced luciferase assay kit (Analytical Luminescence Laboratory, MI). The cells may be distributed in multiwell plates which can be accommodated by a luminometer. A known number of cells is introduced into each one of the wells in an appropriate medium, the candidate compound added, and the culture maintained for at least 12 hours, more usually at least about 24, and not more than about 60 hours, particularly about 48 hours. The culture is then lysed in an appropriate buffer, using a non-ionic detergent, e.g. 1% triton X-100. The cells are then promptly assayed. In conjunction with the candidate compound, an inducing compound, *e.g.* androgens, will also be added such as methyl trienolene (R1881), or dihydrotestosterone (DHT). The concentration of these inducing agents will vary depending upon the nature of the agent, but will be sufficient to induce expression. The concentration with R1881 will generally be in the range of about 0.1 - 10 nM, preferably about 1 nM.

Any other technique for detecting the level of luminescence may be used. The particular manner of measuring luminescence is not critical to the invention.

The following examples are offered by way of illustration and not by way of limitation.

EXAMPLES

EXAMPLE 1

Preparation and testing of PSA-Luciferase constructs

Materials and Methods

Cells and Culture Methods. LNCaP cells were obtained at passage 9 from the American Type Culture Collection (Rockville, MD). LNCaP cells were maintained in RPMI 1640 medium (RPMI) supplemented with 10% fetal bovine serum (FBS; Intergen Corp.), 100 units/mL of penicillin,, and 100 units/mL streptomycin. LNCaP cells being assayed for luciferase expression were maintained in 10% strip-serum (charcoal/dextran treated fetal bovine serum to remove T3, T4, and steroids; Gemini Bioproduct, Inc., Calabasas, CA) RPMI. The cells were periodically tested for the production of PSA which was consistently above 20 ng/mL per day.

Selection for a stably integrated plasmid DNA was performed in RPMI medium containing G418 (GibcoBRL, NY). The level of G418 in RPMI was decreased from 500 to 100 µg/mL after selection of the parental LNCaP clones for evaluation; these clones were maintained in 100 µg/mL G418 at all times prior assaying. Subclones having enhanced luciferase activity were obtained from the parental cell line by the method of limited dilution cloning.

PSE-Luciferase (CN1) Plasmid Constructs. The luciferase gene from *Photinus pyralis* from the plasmid pJD206 (de Wet et al. *Molecular and Cellular Biology* (1987) 7:725-737) was excised by cleavage with restriction enzymes HindIII and BamHI, then ligated into similarly cleaved pUC18. This plasmid was then cleaved with HindIII and KpnI again to remove the luciferase fragment which was then ligated into similarly cleaved pBluescript KSII(+) (Stratagene). The resulting plasmid was designated LB78. The 5.8 kb HindIII

fragment containing the PSA gene upstream region was excised from the plasmid CN0 (Schuur et al., *J. Biol. Chem.* (1996) 271:7043-7051) and ligated to HindIII-cleaved LB78. A clone was selected with the cap site of the PSA gene in the PSA gene fragment adjacent to the beginning of the luciferase gene to drive its synthesis. The resulting clone was designated CN1 (PSE-Luc).

Transfections of LNCaP Cells. For transfections, LNCaP cells were plated out at a cell density of 5 x 10^5 cells per 6-cm culture dish (Falcon, NJ) in complete RPMI. DNAs were introduced into LNCaP cells after being complexed with a 1/1 molar lipid mixture of N-[1-(2,3-dioleyloxy)propyl-*N,N,N*-trimetylammonium chloride (DOTAP; Avanti Polar Lipids, AL) and dioleoyl-phosphatidylethanolamine (DOPE; Avanti Polar Lipids, AL); DNA/lipid complexes were prepared in serum-free RPMI at a 2/1 molar ratio. Typically, 8 µg (24.2 nmole) of DNA was diluted into 200 µL of incomplete RPMI and added dropwise to 50 nmole of transfecting, lipids in 200 µL of RPMI with gentle vortexing to insure homogenous mixing of components. The DNA/lipid complexes were allowed to anneal at room temperature for 15 minutes prior to their addition to LNCaP cells. Medium was removed from LNCaP cells and replaced with 1 mL of serum-free RPMI followed by the dropwise addition of DNA/lipid complexes. Cells were incubated with complexes for 4-5 hours at 37°C, 5% CO_2. Medium was removed and cells washed once with PBS. The cells were then trypsinized and resuspended in 10% strip-serum RPMI (phenol red free). Cells were replated into an opaque 96-well tissue culture plate (Falcon, NJ) at a cell density of 40,000 cells/well per 100 µL media and assayed. Varying amounts of drugs (e.g. androgens and anti-androgens) were added 16 hours later and assayed for luciferase activity 32 hours thereafter.

Generation of a stably transfected cell line expressing luciferase was accomplished by co-transfecting the plasmid pcDNA3 with PSE-Luc. The neomycin gene of pcDNA3 confers resistance to the antibiotic G418, allowing selection of stably transfected LNCaP cells. LNCaP cells were co-transfected with PSE-Luc and pcDNA3 as described for transient transfections. Briefly, 1 µg of pcDNA3 and 1-10 µg of PSE-Luc were diluted into 200 µL of RPMI and complexed with two molar equivalents of DOTAP/DOPE (1:1) in 200 µL RPMI. Addition of DNA to lipids was dropwise with gentle vortexing to homogeneously mix the

samples. After annealing the complexes for 15 minutes, they were added dropwise to LNCaP cells in 1 mL RPMI and incubated overnight (12 hours) at 37°C. Media/DNA-lipid complexes were removed from the tissue culture plates and supplemented with complete RPMI containing 500 µg/mL G418. The selection media was kept at 500/µg/mL G418 for three weeks before being lowered to 250 µg/mL. G418 resistant colonies appeared after four weeks and were allowed to grow until visible by eye, upon which colonies were trypsinized (0.25% trypsin) and transferred to a 24 well tissue culture plate, followed by further expansion. Clones were assayed for luciferase expression after they had reached 3-5 x 10^6 cells. Screening identified the clone CN1013 which was selected for further study. A clone 5-10 fold more active than CN1013, designated CN1013.7, was obtained by subcloning the parental line once by limiting dilution.

Induction and Assaying of Transient and Stable PSE-Luc/LNCaP Cells. For both transient and stably transfected LNCaP cells, a variety of androgens and anti-androgens -- methyl trienolone (R1881, DuPont NEN), dihydrotestosterone (DHT, Sigma), cyproterone acetate (CA and hydroxyflutamide (Ho-Flu)-- were used to induce expression of the luciferase reporter gene. Androgens or anti-androgens were prepared at 3x concentrations in 10% strip-serum RPMI and added as 50 µL aliquots to each well of the 96-well plate. Cells were incubated with either androgens or anti-androgens for 48 hours before assaying. Assays were done in triplicate or quadruplicate. The concentration of dihydrotestosterone (DHT) was measured by the Testosterone ELISA Kit (Neogen Corporation). The assay has 100% cross reactivity with DHT.

In the case of stably transfected PSE-Luc/LNCaP clones, media was removed and cells washed with PBS (2 x 20 mL). The clonal cells were then maintained in 10% strip-serum RPMI (phenol red free) for 24 hours prior to trypsinizing and replating into an opaque 96-well plate - 40,000 cells/well per 100 µL media. Cells were allowed to become adherent overnight before the addition of either androgens or anti-androgens. Incubation of clonal cells in strip-serum RPMI prior to induction with drug(s) substantially lowered background luciferase expression.

The luciferase assay of both transient and stably transfected cells was performed in the same manner. After induction of cells with androgens or anti-androgens for 48 hours, media was removed and 50 µL of lysis reagent added (0.1 M potassium phosphate buffer at pH 7.8, 1% Triton X-100, 1 mM dithiothreitol, 2mM EDTA) to each well. Cells were assayed within 15 minutes of lysis or stored at -80°C until analysis. Storage of cell lysates at -80°C for five days or less did not result in significant loss of luciferase activity.

The Enhanced Luciferase Assay Kit (Analytical Luminescence Laboratory, MI) was used to quantitate the extent of luciferase activity from PSE-Luc transfected LNCaP cells. A Dynatech 3000 96-well plate luminometer (Dynatech, VA) was used to measure the amount of light generated from the assay. The instrument was run in the Enhanced Flash Mode, employing a dual injector system for substrate addition. Optimal assay conditions and Luminometer parameters were as follows: addition of 60 µL of Substrate A (buffer), 1 second delay, addition of 60 µL of Substrate B (luciferin reagent), 1 second delay, integrate signal for 3 seconds. The results are depicted as the integral sum in relative light units (RLUs). The extent of induction by androgens/anti-androgens, e.g. fold induction, was determined by: *fold induction = RLUs [x nM drug]/RLUs [0 nM drug].*

CMV-Luc/LNCaP Cell Line. Transfections of the control plasmid, CMV-Luc, into LNCaP cells were done in the same fashion as for PSE-Luc. The stable cell line CN1006, containing CMV-Luc, was obtained by selection with G418. The luciferase assay was performed as described above.

Results

Transient Transfections of LNCaP Cells with PSE-Luc. The effectiveness of utilizing PSE-Luc in transient transfections as a transcription screening assay for agonist/antagonist type molecules was examined in LNCaP cells. This transcription assay was evaluated for its use in a 96-well format. The androgens, methyl trienolone (R1881) and dihydrotestosterone (DHT), were used to induce different degrees of luciferase expression under the control of the prostate-specific enhancer.

The inducibility of PSE-Luc by the synthetic androgen R1881 in transiently transfected LNCaP cells was determined. Cells were plated into an opaque 96-well plate at a cell density of 4 x 10^4 cells/well per 100 µL, followed by 50 µL of a 3x media solution containing either R1881 or DHT. Cells were incubated for 48 hours, lysed and assayed for luciferase expression. The extent of induction was determined by dividing the amount of luciferase expression (RLUs) at X nM hormone by the amount of expression without hormone. At 0 nM R1881, luciferase expression in transfected LNCaP cells was similar to background levels (approximately 1-5 RLUs). The addition of 1-50 nM R1881 resulted in an approximately 275 fold induction of luciferase expression (3,000-3,500 RLUs) over uninduced transfected cells. Peak levels of luciferase expression were obtained at 1 nM R1881, which closely corresponds to physiological levels of androgen. Variations in the amount of DNA/Lipid complexes used in transient transfections resulted in comparable results, however lower DNA concentrations (e.g. 1 and 2 µg DNA) gave smaller RLU values after induction. Lastly, %CV values ranging from 10-30%.

A second androgen, dihydrotestosterone (DHT), was evaluated for its inducibility of transiently transfected LNCaP cells. DHT is a naturally occurring human androgen and the reductive analog of testosterone. The extent of fold induction increased with increasing concentration of DHT. Peak levels of approximately 100 fold were obtained over the background value of 25 RLUs for DHT concentrations of 100 and 200 nM (e.g. 2,500-3,000 RLUs). A comparison of R1881 and DHT shows that approximately 100 fold more DHT is required relative to R1881 to obtain comparable luciferase activity. The difference in fold induction between the two androgens, e.g. 100 vs. 250 fold induction, can be explained by a 2 fold higher background signal for the DHT (12 vs. 25 RLUs), which likely resulted from the particular experimental procedures employed. However, the overall peak expression levels stimulated by the two androgens are comparable. The higher concentration of DHT required to achieve the same luciferase expression levels obtained with R1881 is addressed later.

Androgen and Anti-androgen Responsiveness of Stably Transfected PSE-Luc/LNCaP Cell Line. LNCaP cells were co-transfected with PSE-Luc and pcDNA3 containing the neomycin gene. LNCaP clones containing both genes were selected with G418 and examined

for luciferase expression after induction with either androgen or anti-androgens. As in the case of transient transfections with PSE-Luc, the assay is evaluated in the 96-well format for high throughput screening (HTS) of potential agonist/antagonist.

The hormones R1881 and DHT were utilized to screen for androgen-responsive LNCaP clones containing the PSE-Luc genes. Two clones, designated CN1010 and CN1013, exhibited luciferase activity upon incubation in 1nM R1881 and were characterized further with varying concentrations of R1881 and DHT. The androgen-responsiveness profile of CN1013 is similar to that obtained for transient transfections. Peak values of R1881 induction were obtained at physiological levels (0.1 - 1 nM), while DHT required 100-200 fold greater amounts for comparable expression. The EC_{50} of R1881 in CN1013 was 0.075nM.

The luciferase responsiveness of CN1013 to anti-androgens, hydroxyflutamide (HO-Flu) and cyproterone acetate (Cypro. A), as well as their antagonist behavior to R1881 (1 nM) induced cells was evaluated. Incubation of CN1013 with either anti-androgen resulted in luciferase expression levels similar to that obtained for R1881, but only at elevated concentrations of 100-1,000 fold higher (Figures 1A and 1B): zero or minimal expression was observed at physiological concentrations. The anti-androgens ability to inhibit luciferase expression after induction with 1 nM R1881 is also shown in Figure 1. At all anti-androgen concentrations examined, there was neither inhibition nor induction of luciferase expression after R1881 had been added. The addition of other non-steroidal intracellular receptor ligands unrelated to the androgen receptor, i.e. retinoic acid (RA), did not result in either induction or inhibition of CN1013.

The intra-assay %CVs of the stable cell line CN1013 typically varied between 5-10%. While the initial characterization of CN1013 resulted in %CV slightly higher than 10%, later experiments were able to lower the intra-assay %CV to an acceptable range (Figures 1A and 1B). Transient transfection assays yielded %CVs of 10-30%, whereas stable cell line assays (CN1013), yielded %CVs of 5-10%.

Metabolism of Dihydrotestosterone (DHT) in CN1013 Cell Line. The higher levels of DHT needed to induce luciferase expression in either CN1013 or transient transfections was investigated. The decrease of DHT concentration in CN1013 cells was measured kinetically

utilizing the Testosterone ELISA Kit by Neogen Corporation (100% cross reactivity with DHT). The metabolism of DHT occurs rapidly within 1-4 hours of addition to CN1013 cells, while the DHT concentration remained constant when unexposed to CN1013 cells. The half life of 10 nM DHT in CN1013 cells was calculated to be approximately 1.1 hours. The metabolized product was not identified.

While the overall luciferase expression levels between transient transfections and CN1013 are similar (3000-4000 RLUs), the extent of fold induction upon androgen addition is approximately 5-10 times lower in the latter case due to significant background signal (e.g. 100-200 RLUs). The larger background signal is a result of the requirement of growing CN1013 in hormone containing RPMI. Incubation of CN1013 in 10% strip-serum RPMI (minus hormone) prior to plating into 96-well plates lowered background signal moderately. Further decreases in overall luciferase expression were observed with passage number of the cell line. A comparison of the RLUs at passage 5 and 15 showed an approximate 3-5 fold decrease in luciferase expression, however the overall level of induction remained identical.

The decrease in luciferase expression of CN1013 with increasing passage number resulted in the need to select subclones having enhanced expression levels. Subclones of PSE-Lue/LNCaP were obtained from the parental cell line CN1013 by limiting dilution. Screening of these clones produced a single active clone, designated CN1013.7, which was 5-10 times more active than the parental cell line yielding 100-200 fold induction with R1881.

Luciferase Expression of CMV-Luc/LNCaP Stable Cell Line. LNCaP clones containing the CMV-Luc gene were screened for stable expression of the luciferase gene (i.e. selection of stable cell line). A 3-4 fold increase in expression levels over the uninduced cells was observed upon the addition of 10-1000 nM androgen. A similar androgen stimulation of CMV-Luc expression in transient transfection of LNCaP cells was reported by Pang et al., Hum. Gene Ther. (1995) 6:1417-1426. The slight increase in expression levels was attributed to cell proliferation resulting from increased R1881 addition.

EXAMPLE 2

Construction of reporter constructs in which expression of reporter genes is under the control of the hKLK2 5'-flanking region

To assess the function of the DNA segment containing the enhancer, a series of constructs was generated by inserting the *hKLK2* 5'-flanking region, shown schematically in Figure 2, upstream of the luciferase reporter gene. The activity of these fragments was compared with that of CN299, a plasmid with the full *hKLK2* promoter (-605 to +33) driving the expression of firefly luciferase. The constructs are as follows:

- To clone the *hKLK2* full promoter an approximately 600 bp fragment was amplified with the oligonucleotides 41.100.1 and 42.100.2 (5'-GAT CAC CGG TGC TCA CGC CTG TAA TCT CAT CAC-3' (SEQ ID NO:2), PinAI site underlined). 42.100.2 corresponds to the upstream region of the *hKLK2* promoter. The PCR product was then cloned into pGEM-T vector (Promega) to generate CN294.

- CN299 is a plasmid containing the luciferase coding segment driven by the full *hKLK2* promoter. The full promoter region was released from CN294 by NcoI-SacI digestion and ligated into a similarly cut pGL3-Basic (Promega) to generate CN299.

- CN322 is a plasmid containing the entire structural gene of firefly luciferase driven by the human *hKLK2* promoter and the other all regulatory elements. The entire 12 kbps *hKLK2* 5'-flanking region was excised from CN312 by SacII/SpeI digestion and ligated into SacII/SpeI digested pGL3-Basic to produce CN322.

- CN324 is a luciferase construct containing the *hKLK2* minimal promoter driving the luciferase coding region. The minimal *hKLK2* promoter was released from CN317 by NcoI-SacI digestion and ligated into a similarly cut pGL3-Basic to generate CN324.

- CN325 is the same as CN324, except that a XhoI site (instead of a PinAI site) was created at the 5' end of the minimal promoter.

- CN355 was created by digesting CN340 with XhoI and KpnI. The released fragment (~3.8 kbps) was ligated into CN325, upstream of the minimal promoter.

EXAMPLE 3

Effects of the hKLK2 5'-flanking region

To determine the effect of the 12 kbp 5'-flanking sequence on promoter activity, two constructs were created: CN299 and CN322. The *hKLK2* promoter was cloned upstream of the *luc* gene to create CN299, as described in Example 2. The entire 12 kbp sequence upstream of the *hKLK2* gene (including the promoter) was cloned upstream of the *luc* gene to create CN322, as described in Example 2. Each construct was then used to transfect LNCaP cells. The media in half of the dishes was supplemented with 0.5 nM R1881. The cells were harvested 48 hours post transfection and the luciferase activity was measured. Figures 3A and 3B summarize the data and demonstrate that CN322 has higher activity than CN299. At both R1881 concentrations tested, CN322 had higher activity than CN299. At 0 nM, CN322 was 12 fold more active than CN299. At 0.5 nM, CN322 was approximately 36 fold more active than CN299. These data suggest that the 12 kb 5'-flanking sequence contains an enhancer and that this enhancer is also androgen responsive.

EXAMPLE 4

Characterization of the hKLK2 enhancer

The results of the previous experiment (Example 3) suggested that the luciferase activity of the putative enhancer found in CN322 responded in an androgen dependent manner. To determine if the *hKLK2* 5'-flanking sequence did indeed contain an androgen responsive element, two experiments were conducted. In the first experiment, LNCaP cells were transfected with CN322, the transformants were incubated in medium containing various concentrations of R1881, and 48 hours after transfection, luciferase activity was measured. The results are summarized in Figures 4A and 4B. In short, CN322 responded to the

testosterone analog R1881 in a concentration dependent manner. Peak induction of activity was estimated at 1 nM R1881, about 9 fold over the 0 nM activity.

In the second experiment, the effect of time of incubation in the presence of R1881 on the activity of the 12 kb 5'-flanking sequence was assessed. LNCaP cells were transfected with CN322 and incubated for various periods of time in the presence of 0.5 nM R1881 before harvesting. The results are summarized in Figure 5. The peak luciferase activity was seen at 60 hours post transfection, but the overall upward trend seemed to plateau at about 48 hours post transfection.

To summarize these two experiments, it seemed that the *hKLK2* enhancer appears to be androgen responsive and peak induction of *luc* activity takes place somewhere between 48 and 60 hours post transfection.

EXAMPLE 5

Tissue specificity of the hKLK2 enhancer

Knowing that the *PSA* enhancer is tissue specific, a series of experiments was conducted to determine if the same was true for the *hKLK2* enhancer. In the first experiment, LNCaP cells (a PSA-producing prostate cancer cell line) and 293s (a human embryonic kidney cell line) were transfected with CN299 or CN322 (Example 2). Half of the dishes were supplemented with 1 nM R1881, and the cells were harvested 48 hours post transfection. The LNCaP cells transfected with CN322 exhibited a 17 fold induction of activity in the presence of 1 nM R1881 when compared to the background activity at 0 nM R1881. The 293s transfected with CN322 showed a reduction of luciferase activity in the presence of 1 nM R1881. CN299 exhibited a 2-3 fold induction in the presence of 1 nM R1881, and a reduction of activity in the 293 cells. The results of this first experiment are summarized in Figure 6. The results of this experiment again support the conclusion that the *hKLK2* enhancer is androgen inducible.

Results of earlier experiments indicated that a putative *hKLK2* enhancer may lie between the ApaI site at approximately -6200 bp and the XhoI site at approximately -2400 bp of the *hKLK2* enhancer. This 3.8 kbp fragment was fused upstream of the minimal *hKLK2*

promoter and then cloned upstream of the *luc* gene, creating CN355. A variety of cell lines were transfected with CN322 or CN355 by incubating them with the complexes in complete media overnight. The complexes were then aspirated and the media was replaced with stripped serum media. The media in half of the plates was supplemented with 1 nM R1881. The cells were then harvested 48 hours after the removal of the DNA-lipid complexes and tested for luciferase activity. The results are summarized in Figure 7.

CN322 gave almost a 100 fold induction of activity in the presence of 1 nM R1881 in the LNCaP cells. CN355 exhibited a 35-fold induction of activity under the same conditions. All of the other cell lines, including the prostate-derived cell line PC3, showed little androgen inducibility. In fact, CN322 and CN355 showed only about a 1-2 fold induction in any of the other cell lines. Although the PC3 cell line is prostate derived, it lacks an androgen receptor. To further delineate the sequences required for enhancer activity, the construct CN379 was made, which has, in addition to a minimal *hKLK2* promoter, the region from -5155 to -3412 driving expression of the luciferase gene. Using the same assay methods described above, this construct gave approximately 54-fold induction of luciferase activity in the presence of inducing agent R1881.

These data show that the minimal enhancer constructs CN355 and CN379 retained some of the activity of the full 12 kbps 5'-flanking sequence, indicating that part of the putative *hKLK2* enhancer is between the ApaI and XhoI sites previously described above. The data also support the conclusion that the *hKLK2* enhancer is androgen responsive and that its activity is restricted to cell lines containing an androgen receptor.

It is evident from the above results that simple and rapid screening methods are provided for determining activity of compounds in inhibiting proliferation of prostate cancer. The methods employ cells which are stable, can be easily grown, and can be used in a conventional format to identify the activity of specific compounds. The results are at least semi-quantitative, and allow for high throughput screening with automated equipment.

All publications and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

The invention now being fully described, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the appended claims.

SEQUENCE LISTING

(1) GENERAL INFORMATION

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(ii) TITLE OF THE INVENTION: PROSTATE CANCER DRUG SCRE
ENING

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(v) COMPUTER READABLE FORM:
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(D) SOFTWARE: FastSEQ for Windows Version 2.0

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(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 12047 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

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(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 33 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

GATCACCGGT GCTCACGCCT GTAATCTCAT CAC 33

CLAIMS

What is claimed is:

1. A method for screening drugs for the treatment of prostate cancer employing PSA expressing cells comprising an expression construct which comprises a transcriptional initiation region of the prostate specific antigen enhancer and a promoter and a gene whose expression product provides a detectable signal, wherein said gene is under the transcriptional control of said transcriptional initiation region, said method comprising;

combining said PSA expressing cells with a candidate drug in the presence of an androgen for sufficient time for detectable expression of said gene; and

detecting the level of expression of said gene as compared to the level of expression in the absence of said candidate drug.

2. A method according to Claim 1, wherein said gene expresses an enzyme.

3. A method according to Claim 2, wherein said enzyme is luciferase.

4. A method according to Claim 3, wherein said detecting comprises:

lysing said PSA expressing cells; and

assaying said lysate for luminescence.

5. A method according to Claim 1, wherein said androgen is methyl trienolone or dihydrotestosterone.

6. A method for screening drugs for the treatment of prostate cancer employing PSA expressing cells comprising an expression construct which comprises a transcriptional initiation region of the prostate specific antigen enhancer and a promoter and a gene encoding an enzyme which catalyzes a reaction resulting, in a detectable signal, wherein said gene is under the transcriptional control of said transcriptional initiation region, said method comprising;

combining said PSA expressing cells with a candidate drug in the presence of methyl trienolone or dihydrotestosterone for sufficient time for detectable expression of said enzyme;

lysing said PSA expressing cells to provide a lysate and adding the substrate of said enzyme to said lysate; and

detecting the level of expression of said enzyme as compared to the level of expression in the absence of said candidate drug.

7. A method according to Claim 6, wherein said PSA expressing cells are LNCaP cells and said enzyme is luciferase.

8. A method for screening compounds for the treatment of prostate cancer employing mammalian cells comprising an expression construct, said expression construct comprising an enhancer of a prostate-specific gene and a promoter and a reporter gene whose expression product provides a detectable signal, wherein said reporter gene is under the transcriptional control of said enhancer, said method comprising the steps of:

a) combining said cells with a candidate compound for a sufficient time for detectable expression of said reporter gene; and

b) detecting the level of expression of said reporter gene as compared to the level of expression in the absence of said candidate compound.

9. A method according to claim 8, wherein said reporter gene expresses an enzyme.

10. A method according to claim 9, wherein said enzyme is luciferase.

11. A method according to claim 10, wherein said detecting comprises:
lysing said mammalian cells; and assaying said lysate for luminescence.

12. A method according to claim 8, wherein said enhancer is an enhancer region of the human prostate specific antigen gene.

13. A method according to claim 8, wherein said enhancer is an enhancer region of the human glandular kallikrein (*hKLK2*) gene.

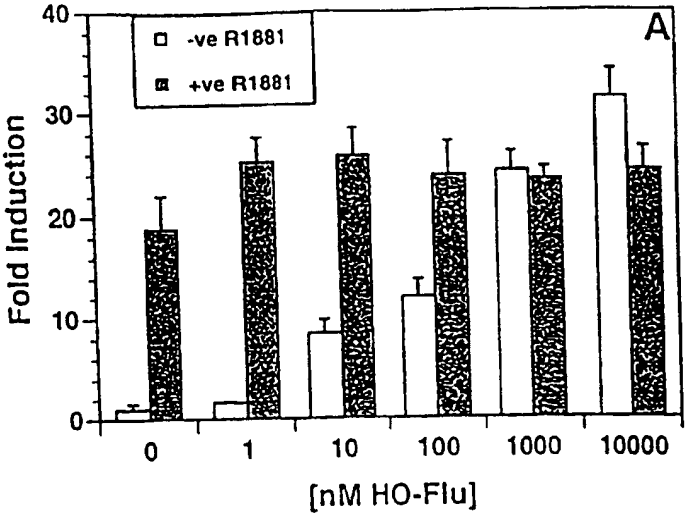
14. The method according to claim 13, wherein the *hKLK2* enhancer encompasses nucleotides 1 to 9765 of SEQ ID NO:1 or active fragments thereof.

15. The method according to claim 13, wherein the *hKLK2* enhancer encompasses nucleotides 5976 to 9620 of SEQ ID NO:1 or active fragments thereof.

16. The method according to claim 13, wherein the *hKLK2* enhancer encompasses nucleotides 6859 to 8627 of SEQ ID NO:1 or active fragments thereof.

17. The method according to claim 13, wherein the mammalian cells are prostate cells containing an endogenous androgen receptor.

18. The method according to claim 13, wherein the enhancer is an *hKLK2* enhancer and the promoter is an *hKLK2* promoter.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+ve R1881
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20
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1000
10000
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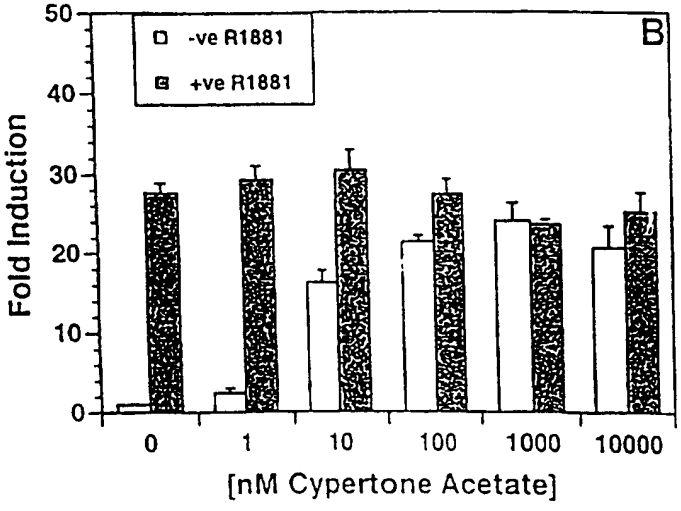
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1000
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Figure 1

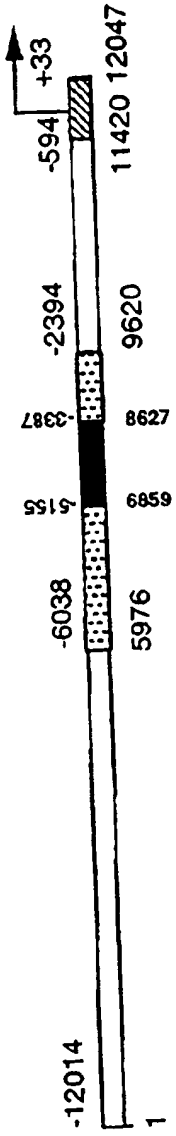
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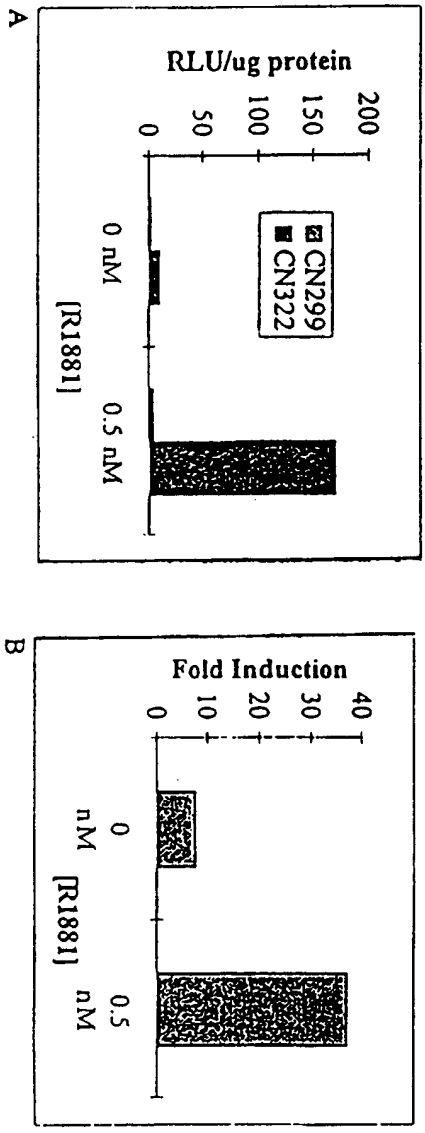
Figure 2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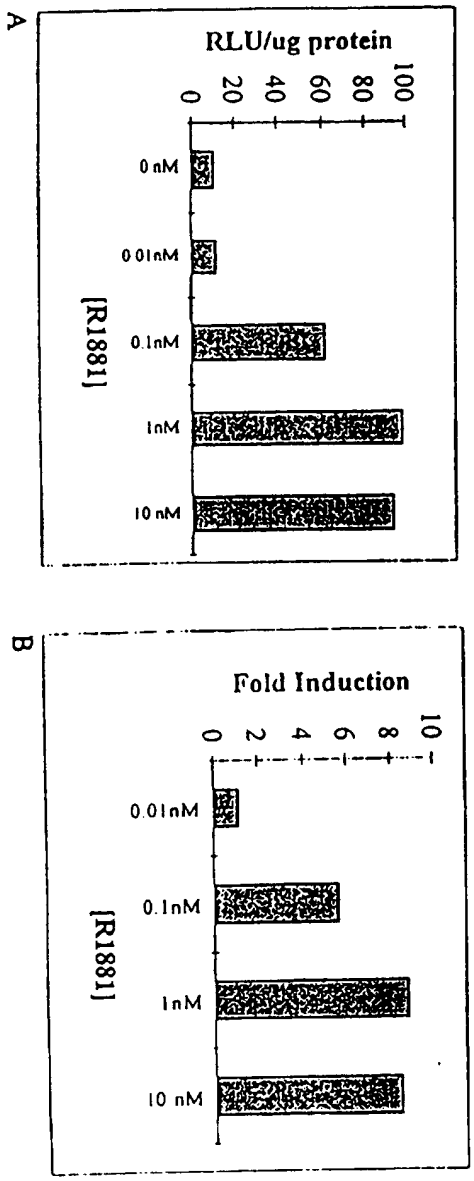
0 nM
0.5 nM
[R1881]

Figure 3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0.1nM
1nM
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[R1881]
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6
8
10
0.01nM
0.1nM
1nM
10 nM
[R1881]

Figure 4

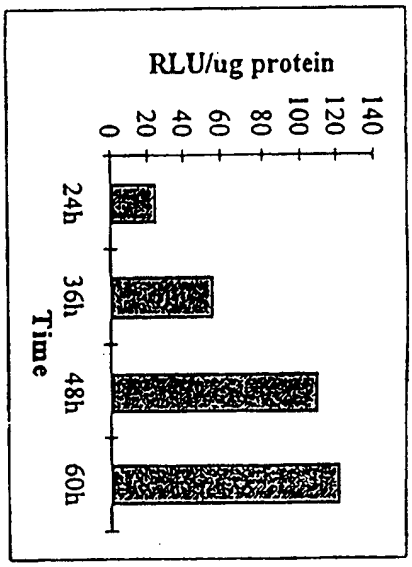


Figure 5

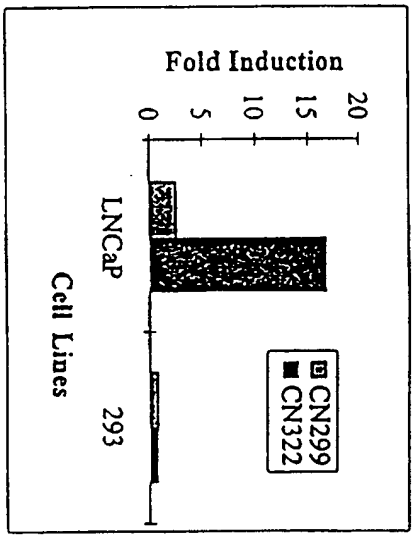
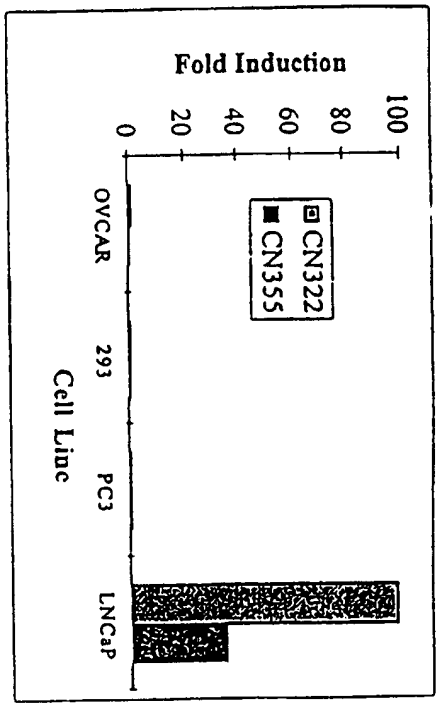


Figure 6


Fold Induction
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20
40
60
80
100
CN322
CN355
OVCAR
293
PC3
LNCaP
Cell Line

Figure 7

INTERNATIONAL SEARCH REPORT

International Application No
T/US 97/13888

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C12Q1/68 G01N33/574

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C12Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SCHUUR E R ET AL: "Prostate -specific antigen expression is regulated by an upstream enhancer." JOURNAL OF BIOLOGICAL CHEMISTRY (MICROFILMS), vol. 271, no. 12, March 1996, MD US, pages 7043-7051, XP002050776 see the whole document specially see page 7044, right-hand column, last paragraph; figure 1 --- -/--	1-12

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 December 1997	15/01/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Molina Galan, E

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PC 97/13888

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication where appropriate, of the relevant passages	Relevant to claim No.
Y	MURTHA P ET AL: "ANDROGEN INDUCTION OF A HUMAN PROSTATE-SPECIFIC KALLIKREIN HKLK2 CHARACTERIZATION OF AN ANDROGEN RESPONSE ELEMENT IN THE 5' PROMOTER REGION OF THE GENE." BIOCHEMISTRY 32 (25). 1993. 6459-6464. CODEN: BICHAW ISSN: 0006-2960, XP002050777 cited in the application see the whole document ---	13-18
Y	WO 95 06754 A (UNIV CALIFORNIA) 9 March 1995 see the whole document ---	1-18
A	WO 95 19434 A (CALYDON INC) 20 July 1995 ---	
A	WILLIAMS T M ET AL: "ADVANTAGES OF IREFLY LUCIFERASE AS A REPORTER GENE: APPLICATION TO THE INTERLEUKIN-2 GENE PROMOTER" ANALYTICAL BIOCHEMISTRY, vol. 176, no. 1, January 1989, pages 28-32, XP000601607 ---	
A	YOUNG ET AL.: "Tissue-specific and hormonal regualtion of human prostate-specific glandular kallikrein" BIOCHEMISTRY, vol. 31, 1992, EASTON, PA US, pages 818-824, XP002050778 cited in the application -----	

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
/US 97/13888

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9506754 A	09-03-95	AU 682398 B	02-10-97
		AU 7719094 A	22-03-95
		CA 2169466 A	09-03-95
		EP 0724648 A	07-08-96
		JP 9502345 T	11-03-97
		NO 960715 A	22-02-96
WO 9519434 A	20-07-95	AU 1686995 A	01-08-95
		CA 2181073 A	20-07-95
		EP 0755443 A	29-01-97
		JP 9509049 T	16-09-97
		US 5648478 A	15-07-97

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International Bureau

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(43) International Publication Date: 12 February 1998 (12.02.98)

(21) International Application Number: PCT/US97/13888

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(30) Priority Data:
08/692,759 6 August 1996 (06.08.96) US
Not furnished 4 August 1997 (04.08.97) US

(60) Parent Application or Grant
(63) Related by Continuation
US Not furnished (CON)
Filed on 4 August 1997 (04.08.97)

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(54) Title: PROSTATE CANCER DRUG SCREENING

(57) Abstract

Screening of compounds for activity toward inhibition of prostate cancer cell proliferation is provided. A cell line is employed which can be used in conventional equipment for determining activity of compounds, where the cell line uses a marker whose expression is responsive to therapeutically active compounds.

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AMENDED CLAIMS

[received by the International Bureau on 14 March 1998 (14.03.98);
original claims 8-18 amended; new claims 19-25 added; remaining claims unchanged (3 pages)]

combining said PSA expressing cells with a candidate drug in the presence of methyl trienolone or dihydrotestosterone for sufficient time for detectable expression of said enzyme;

lysing said PSA expressing cells to provide a lysate and adding the substrate of said enzyme to said lysate; and

detecting the level of expression of said enzyme as compared to the level of expression in the absence of said candidate drug.

7. A method according to Claim 6, wherein said PSA expressing cells are LNCaP cells and said enzyme is luciferase.

8. A method according to claims 1 or 6, wherein the prostate specific antigen enhancer comprises a sequence encompassing nucleotides between about -5824 to about -3738 of the upstream region of the PSA gene, wherein the enhancer exhibits enhancer activity.

9. A method according to claims 1 or 6, wherein the prostate specific antigen enhancer is contained within a polynucleotide fragment of about 5.8 kilobases from about -5824 to about +1 of the upstream region of the PSA gene, wherein the enhancer exhibits enhancer activity.

10. A method according to claim 10, wherein the promoter comprises a sequence encompassing nucleotides between about -560 to about +7 of the PSA gene.

11. A method for screening compounds for the treatment of prostate cancer employing cells comprising an expression construct, said expression construct comprising an enhancer of a prostate-specific gene and a promoter and a reporter gene whose expression product provides a detectable signal, wherein said reporter gene is under the transcriptional control of said enhancer, said method comprising the steps of:

a) combining said cells with a candidate compound for a sufficient time for detectable expression of said reporter gene; and

b) detecting the level of expression of said reporter gene as compared to the level of expression in the absence of said candidate compound.

12. A method according to claim 11, wherein said reporter gene expresses an enzyme.

13. A method according to claim 12, wherein said enzyme is luciferase.

14. A method according to claim 13, wherein said detecting comprises: lysing said cells; and assaying said lysate for luminescence.

15. A method according to claim 11, wherein said enhancer is an enhancer region of the human prostate specific antigen (PSA) gene.

16. A method according to claim 15, wherein the prostate specific antigen enhancer comprises a sequence encompassing nucleotides between about -5824 to about -3738 of the upstream region of the PSA gene, wherein the enhancer exhibits enhancer activity.

17. A method according to claim 11, wherein said enhancer from the human glandular kallikrein (*hKLK2*) gene.

18. A method according to claim 17, wherein the *hKLK2* enhancer comprises a sequence encompassing nucleotides about 1 to about 9765 of SEQ ID NO:1 or active fragments thereof.

19. A method according to claim 17, wherein the *hKLK2* enhancer comprises a sequence encompassing nucleotides about 5976 to about 9620 of SEQ ID NO:1 or active fragments thereof.

20. A method according to claim 17, wherein the *hKLK2* enhancer comprises a sequence encompassing nucleotides about 6859 to about 8627 of SEQ ID NO:1 or active fragments thereof.

21. A method of any of claims 17 to 20, wherein the promoter is an *hKLK2* promoter.

22. A method of any of claims 11 to 21, wherein the cells are mammalian.

23. A method of claim 22, wherein the mammalian cells express prostate specific antigen.

24. A method of claim 22 or 23, wherein the cells are prostate.

25. A method of claim 24, wherein the prostate cells contain an endogenous androgen receptor.

AMENDED SHEET (ARTICLE 19)

CORRECTED VERSION*

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PROSTATE CANCER DRUG SCREENING

TECHNICAL FIELD

The present invention relates to screening methods for identifying compounds useful in the treatment of prostate cancer.

BACKGROUND

Prostate cancer is the fastest growing neoplasm in men with an estimated 244,000 new cases in the United States being diagnosed in 1995, of which approximately 44,000 deaths will result. Hormonal ablation therapy, either surgically or chemically with anti-androgens, is the main stay of treatment for advanced carcinoma of the prostate. However, androgen ablation therapy failed within 12-18 months with the disease becoming androgen independent. Following the failure of androgen therapy, the median patient survival time is eight months. Other approaches to treating prostate cancer -- external radiation, radioactive seed therapy, cryotherapy, etc.-- are directed toward organ confined disease of the prostate and are unable to treat metastatic tumors.

The prostate-specific antigen (PSA), a member of the human kallikrein gene family, is a Mr = 34,000 chymotrypsin like protein that is synthesized exclusively by normal, hyperplastic, and malignant prostatic epithelia. Hence, the PSA's tissue-specific relationship has made it an excellent biomarker for identifying benign prostatic hyperplasia (BPH) and prostatic carcinoma (CaP), hereinafter CaP. Normal serum levels of PSA in blood are typically below 5 ng/ml, with elevated levels indicative of BPH or CaP. Serum levels of 200 ng/ml have been measured in end-stage metastatic CaP.

Another member of the kallikrein gene family, human glandular kallikrein-1 (*hGK-1* or *hKLK2*, encoding the hK2 protein), shares a number of characteristics with PSA. First, both are expressed exclusively in the prostate and are up-regulated by androgens primarily by

transcriptional activation. Wolf et al. (1992) *Molec. Endocrinol.* 6:753-762. Morris (1989) *Clin. Exp. Pharm. Physiol.* 16:345-351; Qui et al. (1990) *J. Urol.* 144:1550-1556; Young et al. (1992) *Biochem.* 31:818-824. Second, *hKLK2* and *PSA* mRNAs are synthesized and co-localize only in prostatic epithelia. Third, *hKLK2* and *PSA* exhibit a high degree of amino acid sequence identity. Schedlich et al. (1987) *DNA* 6:429-437. Fourth, they have similar regulatory elements. There is approximately 80% nucleotide sequence identity between *PSA* and *hKLK2* in the 5'-flanking region from -300 to -1 relative to the transcription initiation site. Young et al. (1992) *Biochem.* 31:818-824. Each promoter contains an androgen responsive element (ARE); their respective ARE's differ from one another by only 1 nucleotide. Schedlich et al. (1987) *DNA* 6:429-437; Murtha et al. (1993) *Biochem.* 32:6459-6464.

The levels of hK2 found in various tumors and in the serum of patients with prostate cancer differ substantially from those of PSA. Circulating hK2 in different relative proportions to PSA has been detected in the serum of patients with prostate cancer. Charlesworth et al. (1997) *Urology* 49:487-493. Expression of hK2 has been detected in each of 257 radical prostatectomy specimens analyzed. Darson et al. (1997) *Urology* 49:857-862. The intensity and extent of hK2 expression, detected using specific antibodies, increased from benign epithelium to high-grade prostatic intraepithelial neoplasia (PIN) and adenocarcinoma, whereas PSA and prostate acid phosphatase (PAP) displayed an inverse pattern of immunoreactivity. Darson et al. (1997) *Urology* 49:857-862. Indeed, it has been reported that a certain percentage of PSA-negative tumors have detectable hK2. Tremblay et al. (1997) *Am. J. Pathol.* 150:455-459.

As mentioned above, both *PSA* and *hKLK2* genes are up-regulated by androgens primarily by transcriptional activation. Androgen induction of gene expression requires the presence of an androgen receptor (AR). Typically, an androgen diffuses passively into the cell where it binds AR. The androgen-activated AR binds to specific DNA sequences called androgen-responsive elements (AREs or ARE sites). Once anchored to an ARE, the AR is able to regulate transcriptional activity in either a positive or negative fashion. Lindzey et al. (1994) *Vitamins and Hormones* 49: 383-432.

The AR belongs to a nuclear receptor superfamily whose members are believed to function primarily as transcription factors that regulate gene activity through binding to specific DNA sequences, hormone-responsive elements. Carson-Jurica et al. (1990) *Endocr. Rev.* 11: 201-220. This family includes the other steroid hormone receptors as well as the thyroid hormone, the retinoic acid and the vitamin D_3 receptors. The progesterone and glucocorticoid receptor are structurally most closely related to the AR. Tilley et al. (1989) *Proc. Natl. Acad. Sci. USA* 86: 327-331; Zhou et al. (1994) *Recent Prog. Horm. Res.* 49: 249-274; and Lindzey et al. (1994) *Vit. Horm.* 49: 383-432.

The AR gene itself is a target of androgenic regulation. In the prostate cancer cells lines PC3 and DU145, which do not express an endogenous AR, androgenic up-regulation of AR cDNA expression occurred in the transfected cells. Dai et al. (1996). Androgenic up-regulation of AR mRNA and protein was observed in PC3 cells that were stably transfected with the AR cDNA, suggesting that AR mRNA regulation also occurs when the cDNA is organized into chromatin. Dai et al. (199[illegible].

The characterization of genes whose expression is limited to the prostate allows the development of screening methods which can identify substances capable of specifically altering the expression of prostate-specific genes.

In the last few years, numerous techniques have been developed for producing vast arrays of potential drug-like compounds. These compounds include not only oligomers, such as oligopeptides and oligonucleotides, but also synthetic organic compounds based on various core structures. In addition, various natural sources have been screened for active compounds, such as those found in jungles, the ocean and the like. Thus, there is a great proliferation of available compounds for screening for physiological activity.

The process of identifying prospective compounds having therapeutic activity is primarily held back by the absence of useful screening assays. In order for a screening assay to be useful, it should be capable of automation, allow for the screening of large numbers of samples without requiring extensive equipment or housing, be relatively inexpensive, and provide for a clear indication of activity. There is, therefore, substantial interest in identifying

new screening assays which would allow for the screening of compounds which may have therapeutic activity in relation to prostate cancer.

SUMMARY OF THE INVENTION

Methods and compositions are provided for screening therapeutic agents for the treatment of prostate cancer. The methods employ a PSA expressing stably transformed epithelial cell line comprising a construct of the PSA gene enhancer/promoter and a marker gene, e.g. luciferase. The cells are shown to be responsive to the addition of androgen agonists and antagonists by the modified expression of the marker gene. The methods also employ a cell line derived from the prostate, which cell line is stably transformed with a construct comprising a transcriptional control region of a gene, such as PSA or *hKLK2*, whose expression is substantially limited to cells of the prostate, and a reporter gene. Alterations in the levels of reporter gene product in the presence of a candidate agent or compound are indicative of a potential therapeutic agent.

Accordingly, in one aspect, the invention includes a method for screening drugs for the treatment of prostate cancer employing PSA expressing cells comprising an expression construct which comprises a transcriptional initiation region of the prostate specific antigen enhancer and a promoter and a gene whose expression product provides a detectable signal, wherein said gene is under the transcriptional control of said transcriptional initiation region, said method comprising combining said PSA expressing cells with a candidate drug in the presence of an androgen for sufficient time for detectable expression of said gene, and detecting the level of expression of said gene as compared to the level of expression in the absence of said candidate drug.

In another aspect, the invention provides a method A method for screening drugs for the treatment of prostate cancer employing PSA expressing cells comprising an expression construct which comprises a transcriptional initiation region of the prostate specific antigen enhancer and a promoter and a gene encoding an enzyme which catalyzes a reaction resulting, in a detectable signal, wherein said gene is under the transcriptional control of said transcriptional initiation region, said method comprising combining said PSA expressing cells

with a candidate drug in the presence of methyl trienolone or dihydrotestosterone for sufficient time for detectable expression of said enzyme, lysing said PSA expressing cells to provide a lysate and adding the substrate of said enzyme to said lysate, and detecting the level of expression of said enzyme as compared to the level of expression in the absence of said candidate drug.

In another aspect, the invention provides a method for screening compounds for the treatment of prostate cancer employing mammalian cells comprising an expression construct, said expression construct comprising an enhancer of a prostate-specific gene and a promoter and a reporter gene whose expression product provides a detectable signal, wherein said reporter gene is under the transcriptional control of said enhancer, said method comprising the steps of combining said cells with a candidate compound for a sufficient time for detectable expression of said reporter gene, and detecting the level of expression of said reporter gene as compared to the level of expression in the absence of said candidate compound.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a bar graph of anti-androgen induction/inhibition on luciferase expression by the cell line CN1013, Figure 1A indicating induction by hydroxyflutamide, and Figure 1B by cyproterone acetate, before (white bars) and after (dark bars) induction with 1 nM R1881.

Figure 2 is a schematic representation of the hK2 promoter/enhancer region (SEQ ID NO:1). The hatched bar represents the promoter region (Schedlich et al. (1987); GenBank accession number M18156); the dotted portion (including the solid portion) represents an enhancer region; the solid portion represents a smaller region with enhancer activity; and the transcription initiation site is indicated by a bent arrow.

Figures 3A and 3B are bar graphs of testosterone analog R1881 induction of *hKLK2* promoter/enhancer-driven luciferase expression in LNCaP (human metastatic prostate adenocarcinoma) cells. LNCaP cells were transfected with reporter gene constructs, incubated in the presence or absence of inducer, and, 48 hours after transfection, luciferase activity was measured. Figure 3A shows induction, expressed in relative light units (RLU) per μg total protein, of luciferase expression by the *hKLK2* promoter-containing construct CN299

(stippled bars) or by the *hKLK2* promoter/enhancer-containing construct CN322 (solid bars) in the presence of 0 nM or 0.5 nM R1881. Figure 3B shows the fold induction calculated by comparing CN322 RLU/μg protein with CN299 RLU/μg protein in the presence of 0.5 nM R1881.

Figures 4A and 4B are bar graphs of the concentration dependence of R1881-mediated induction of *hKLK2* promoter/enhancer-driven luciferase expression. LNCaP cells were transfected with CN322 and cells were incubated in various concentrations of R1881. Cells were harvested 48 hours after transfection and luciferase activity was measured. Figure 4A shows luciferase activity, expressed as RLU/μg protein, from cultures incubated in the presence of 0, 0.01, 0.1, 1, or 10 nM R1881. Figure 4B shows fold induction calculated by comparing RLU/μg protein at a given concentration to RLU/μg protein at 0 nM R1881.

Figure 5 is a bar graph showing induction of luciferase activity as a function of time of incubation with R1881. LNCaP cells were transfected with CN322 and cells were incubated in medium containing 0.5 nM R1881 for various periods of time, after which luciferase activity was measured.

Figure 6 is a bar graph depicting the cell type specificity of *hKLK2* promoter/enhancer-driven luciferase expression. LNCaP or 293 (human embryonal kidney) cells were transfected with CN299 or with CN322 plasmid constructs and incubated in the absence or the presence of 1 nM R1881. Cells were harvested 48 hours post transfection and luciferase activity was measured. Fold induction was calculated by comparing RLU/μg protein with and without 1 nM R1881.

Figure 7 is a bar graph depicting the activity of the *hKLK2* enhancer/promoter in various cell lines. Various cell lines were transfected with either CN322 or CN355, and, after an overnight incubation in complete medium, were incubated in the presence or absence of R1881. CN355 contains a 3.8 kb fragment from approximately -6200 to approximately -2400 of the *hKLK2* enhancer fused to the minimal *hKLK2* promoter to control luciferase expression. The cell lines used were: OVCAR, human ovarian adenocarcinoma; 293, transformed human primary embryonal kidney; PC3, human grade IV prostate adenocarcinoma; LNCaP, metastatic human prostate adenocarcinoma.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Methods are provided for screening compounds for therapeutic effect against prostate cancer. The methods comprise adding the compound in an appropriate medium to PSA producing cells into which has been stably introduced a genetic construct comprising the enhancer/promoter of the prostate-specific antigen (PSA) with a structural gene under the transcriptional regulation of the PSA enhancer/promoter.

Alternatively, the methods comprise adding the compound in an appropriate medium to cells, preferably derived from the prostate, into which has been stably introduced a genetic construct comprising a transcriptional control region of a prostate-specific gene with a structural gene under the transcriptional regulation of the prostate-specific gene transcriptional control region, which structural gene provides for a detectable, quantifiable signal. Examples of prostate-specific genes include, but are not limited to, PSA and *hKLK2*. By measuring the effect of the candidate compound on the level of signal observed as compared to a basal level, one can evaluate the potential of the compound as a therapeutic agent for the treatment of prostate cancer. Particularly, anti-androgenic activity can be evaluated as indicative of therapeutic effects for prostate cancer, although any compound which modifies the expression of a prostate-specific gene, whatever its mode of action, may be considered a candidate compound.

Cells which are suitable for use in the screening methods of the present invention are mammalian cells in which at least one prostate-specific gene is expressed in the cells. Preferably, the cells are prostate cells, more preferably expressing endogenous androgen receptor, even more preferably prostate epithelial cells expressing endogenous androgen receptor. Preferably, the cells employed display expression of the prostate-specific gene whose transcriptional control region, in whole or in part, is contained within the construct used to stably transform the cells. Alternatively, the cells need not be derived from the prostate as long as the normal function of the transcription regulatory elements of the prostate-specific gene is maintained. This may be achieved, for example, by co-transfecting the cell with a gene encoding a product necessary for the normal function of the promoter/enhancer region of

the prostate-specific gene. For example, if the promoter/enhancer region of the prostate-specific gene is inducible by androgen, it may be necessary to co-transfect into the cells a construct which encodes and allows expression of a gene encoding an androgen receptor.

"Androgen receptor" as used herein refers to a protein whose function is to specifically bind to androgen and, as a consequence of the specific binding, recognize and bind to an androgen response element (ARE), following which the AR is capable of regulating transcriptional activity. The AR is a nuclear receptor that, when activated, binds to cellular androgen-responsive element(s). In normal cells the AR is activated by androgen, but in non-normal cells (including malignant cells) the AR may be activated by non-androgenic agents, including hormones. Encompassed in the term "androgen receptor" are mutant forms of an androgen receptor, as long as the function is sufficiently preserved. Mutants include androgen receptors with amino acid additions, insertions, truncations and deletions, as long as the function is sufficiently preserved.

The term "prostate-specific gene" as used herein indicates a gene whose expression is substantially limited to cells of the prostate, in particular to prostate epithelial cells, and whose expression is substantially undetectable in normal cells derived from tissues other than the prostate.

The term "transcriptional control region" as used herein encompasses enhancers, promoter elements and/or any other nucleotide sequence which controls the level of transcription of a coding region.

The prostate-specific gene whose transcription control region is operably linked with a reporter gene may or may not be one whose expression in prostate cells or cell derived from the prostate is inducible, but preferably is inducible. The term "inducible gene" is used herein to indicate a gene which is normally transcriptionally silent in prostate cells or whose expression is substantially undetectable, and whose expression, in the presence of an appropriate inducing agent, is increased at least 10-fold, more preferably at least about 10- to about 50- fold, even more preferably about 50- to about 200-fold, relative to expression in the absence of the inducing agent.

An inducing agent can be any compound which is added to the growth environment of the cell and which, upon contact with and/or entry into the cell, results in the expression of a specific gene or set of genes. For the purposes of the present invention, an "appropriate inducing agent" is one which specifically induces the expression of a gene which is operably linked to a reporter gene. For example, both PSA and *hKLK2* enhancers are inducible with androgen. An example of an inducing agent used is R1881, a testosterone analog.

In one embodiment, the cells which are employed in the screening are stable prostate cancer cell lines which express PSA, particularly based on the LNCaP cell line, which are cells derived from a metastatic tumor isolated from a lymph node. This cell line has been established for an extended period of time, stably maintains expression of PSA, and is readily grown in conventional media.

In this embodiment, the subject cells are produced by introducing an expression construct into a stable prostate cancer cell line expressing PSA at least a level of 10 to 20 ng/mL per 10^6 cells per day. The expression construct comprises as the transcriptional initiation regulatory region, the PSA enhancer with the PSA promoter or a different promoter region, usually the PSA promoter. The 5' non-coding region of the PSA gene may include the region from 0 (the site of transcription initiation) to -6000 or may be truncated, to provide only those sequences essential for the enhancer region and the promoter region. Thus, the particular regions include the enhancer active sequences between -5824 and -3738 with the promoter active region, for the PSA gene, the region from about -560 to +7.

In another embodiment, the cells employed are mammalian cells (preferably prostate cells, even more preferably LNCaP cells) and the expression construct comprises, as the transcriptional initiation regulatory region, an hK2 enhancer with a promoter which may be an *hKLK2* promoter or a heterologous promoter. The 5' non-coding region of the *hKLK2* gene may include the region from +33 (relative to the site of transcription initiation) to -12,014 or may be truncated to provide only those sequences essential for enhancer function and/or promoter function. Particular regions include an approximately 1.7 kb enhancer active fragment from -5155 to -3387 relative to the transcription start site (nucleotides 6859 to 8627 of SEQ ID NO:1), with the promoter active region being the region from about -600 to about

+33 relative to the transcription start site (from about 11420 to 12047 of SEQ ID NO:1). The DNA sequence as such can vary in length and/or nucleotide sequence as long as the requisite function is maintained.

This transcription initiation regulatory region may then be joined to a marker gene which provides for a detectable, desirably quantifiable, signal. Of particular interest are genes which provide for luminescence, such as luciferase, aequorian, β-galactosidase, chloramphenicol acetyl transferase, etc. In addition, one may provide for a marker for selection comprising a constitutive transcriptional initiation region and an antibiotic resistance gene, e.g. neo. In this way, one may select for those cells which have the expression construct stably integrated.

Marker genes, or reporter genes, which may be employed are known to those skilled in the art and include, but are not limited to, luciferase; aequorian (i.e., green fluorescent protein from *Aequorea victoria*); β-galactosidase;, chloramphenicol acetyl transferase; immunologically detectable protein "tags" such as human growth hormone; and the like. See, for example, Current Protocols in Molecular Biology (F.M. Ausubel et al., eds., 1987) and periodic updates. Any assay which detects a product of the reporter gene, either by directly detecting the protein encoded by the reporter gene or by detecting an enzymatic product of a reporter gene-encoded enzyme, is suitable for use in the present invention. Assays include colorimetric, fluorimetric, or luminescent assays or even, in the case of protein tags, radioimmunoassays or other immunological assays. Many of these assays are commercially available.

The construct may be prepared in accordance with conventional ways, introducing each of the components of the construct into a plasmid by employing convenient restriction sites, PCR (polymerase chain reaction) to introduce specific sequences at the termini, which may include providing for restriction sites, and the like. After the expression construct has been prepared, it may be introduced into the cells by any convenient means.

Methods for introducing the expression construct into the cells or cell lines include transfection, complexing with cationic compounds, lipofection, electroporation, and the like. The cells may be expanded and then screened for the presence of the expression construct.

Where an antibiotic resistance gene has been introduced, the cells may be selected for antibiotic resistance and the antibiotic resistance cells then screened for luminescence under appropriate conditions. In the absence of the antibiotic resistance, the cells may be directly screened for luminescence. Conveniently, the assay for luminescence is performed on a lysate using conventional reagents.

After selecting clones which demonstrate high levels of luciferase activity when activated, the induction ratio may be further enhanced by performing limiting dilution with the cells and screening the resulting clones. In this manner, the induction may be at least 20 fold when induced with an inducing agent such as 0.1 - 1.0 nM R1881, preferably at least about 50 fold, and more preferably at least about 100 fold. Usually, the induction will not exceed about 500 fold.

When the prostate-specific gene used to transform the cell is hormone-inducible, cells are desirably grown in hormone-free medium, *e.g.* RPMI medium supplemented with 10% fetal bovine serum, 100 units/ml penicillin and 100 µg/ml streptomycin, and assayed in hormone spiked medium, e.g. 10% strip-serum RPMI with hormone. Desirably, the cells should not have been passaged more than about 50 times, more desirably not more than about 25 times.

The luminescence may be determined in accordance with conventional commercial kits, e.g. enhanced luciferase assay kit (Analytical Luminescence Laboratory, MI). The cells may be distributed in multiwell plates which can be accommodated by a luminometer. A known number of cells is introduced into each one of the wells in an appropriate medium, the candidate compound added, and the culture maintained for at least 12 hours, more usually at least about 24, and not more than about 60 hours, particularly about 48 hours. The culture is then lysed in an appropriate buffer, using a non-ionic detergent, e.g. 1% triton X-100. The cells are then promptly assayed. In conjunction with the candidate compound, an inducing compound, *e.g.* androgens, will also be added such as methyl trienolene (R1881), or dihydrotestosterone (DHT). The concentration of these inducing agents will vary depending upon the nature of the agent, but will be sufficient to induce expression. The concentration with R1881 will generally be in the range of about 0.1 - 10 nM, preferably about 1 nM.

Any other technique for detecting the level of luminescence may be used. The particular manner of measuring luminescence is not critical to the invention.

The following examples are offered by way of illustration and not by way of limitation.

EXAMPLES

EXAMPLE 1

Preparation and testing of PSA-Luciferase constructs

Materials and Methods

Cells and Culture Methods. LNCaP cells were obtained at passage 9 from the American Type Culture Collection (Rockville, MD). LNCaP cells were maintained in RPMI 1640 medium (RPMI) supplemented with 10% fetal bovine serum (FBS; Intergen Corp.), 100 units/mL of penicillin,, and 100 units/mL streptomycin. LNCaP cells being assayed for luciferase expression were maintained in 10% strip-serum (charcoal/dextran treated fetal bovine serum to remove T3, T4, and steroids; Gemini Bioproduct, Inc., Calabasas, CA) RPMI. The cells were periodically tested for the production of PSA which was consistently above 20 ng/mL per day.

Selection for a stably integrated plasmid DNA was performed in RPMI medium containing G418 (GibcoBRL, NY). The level of G418 in RPMI was decreased from 500 to 100 µg/mL after selection of the parental LNCaP clones for evaluation; these clones were maintained in 100 µg/mL G418 at all times prior assaying. Subclones having enhanced luciferase activity were obtained from the parental cell line by the method of limited dilution cloning.

PSE-Luciferase (CN1) Plasmid Constructs. The luciferase gene from *Photinus pyralis* from the plasmid pJD206 (de Wet et al. *Molecular and Cellular Biology* (1987) 7:725-737) was excised by cleavage with restriction enzymes HindIII and BamHI, then ligated into similarly cleaved pUC18. This plasmid was then cleaved with HindIII and KpnI again to remove the luciferase fragment which was then ligated into similarly cleaved pBluescript KSII(+) (Stratagene). The resulting plasmid was designated LB78. The 5.8 kb HindIII

fragment containing the PSA gene upstream region was excised from the plasmid CN0 (Schuur et al., *J. Biol. Chem.* (1996) 271:7043-7051) and ligated to HindIII-cleaved LB78. A clone was selected with the cap site of the PSA gene in the PSA gene fragment adjacent to the beginning of the luciferase gene to drive its synthesis. The resulting clone was designated CN1 (PSE-Luc).

Transfections of LNCaP Cells. For transfections, LNCaP cells were plated out at a cell density of 5 x 10^5 cells per 6-cm culture dish (Falcon, NJ) in complete RPMI. DNAs were introduced into LNCaP cells after being complexed with a 1/1 molar lipid mixture of N-[1-(2,3-dioleyloxy)propyl-*N,N,N*-trimetylammonium chloride (DOTAP; Avanti Polar Lipids, AL) and dioleoyl-phosphatidylethanolamine (DOPE; Avanti Polar Lipids, AL); DNA/lipid complexes were prepared in serum-free RPMI at a 2/1 molar ratio. Typically, 8 µg (24.2 nmole) of DNA was diluted into 200 µL of incomplete RPMI and added dropwise to 50 nmole of transfecting, lipids in 200 µL of RPMI with gentle vortexing to insure homogenous mixing of components. The DNA/lipid complexes were allowed to anneal at room temperature for 15 minutes prior to their addition to LNCaP cells. Medium was removed from LNCaP cells and replaced with 1 mL of serum-free RPMI followed by the dropwise addition of DNA/lipid complexes. Cells were incubated with complexes for 4-5 hours at 37°C, 5% CO_2. Medium was removed and cells washed once with PBS. The cells were then trypsinized and resuspended in 10% strip-serum RPMI (phenol red free). Cells were replated into an opaque 96-well tissue culture plate (Falcon, NJ) at a cell density of 40,000 cells/well per 100 µL media and assayed. Varying amounts of drugs (e.g. androgens and anti-androgens) were added 16 hours later and assayed for luciferase activity 32 hours thereafter.

Generation of a stably transfected cell line expressing luciferase was accomplished by co-transfecting the plasmid pcDNA3 with PSE-Luc. The neomycin gene of pcDNA3 confers resistance to the antibiotic G418, allowing selection of stably transfected LNCaP cells. LNCaP cells were co-transfected with PSE-Luc and pcDNA3 as described for transient transfections. Briefly, 1 µg of pcDNA3 and 1-10 µg of PSE-Luc were diluted into 200 µL of RPMI and complexed with two molar equivalents of DOTAP/DOPE (1:1) in 200 µL RPMI. Addition of DNA to lipids was dropwise with gentle vortexing to homogeneously mix the

samples. After annealing the complexes for 15 minutes, they were added dropwise to LNCaP cells in 1 mL RPMI and incubated overnight (12 hours) at 37°C. Media/DNA-lipid complexes were removed from the tissue culture plates and supplemented with complete RPMI containing 500 μg/mL G418. The selection media was kept at 500/μg/mL G418 for three weeks before being lowered to 250 μg/mL. G418 resistant colonies appeared after four weeks and were allowed to grow until visible by eye, upon which colonies were trypsinized (0.25% trypsin) and transferred to a 24 well tissue culture plate, followed by further expansion. Clones were assayed for luciferase expression after they had reached 3-5 x 10^6 cells. Screening identified the clone CN1013 which was selected for further study. A clone 5-10 fold more active than CN1013, designated CN1013.7, was obtained by subcloning the parental line once by limiting dilution.

Induction and Assaying of Transient and Stable PSE-Luc/LNCaP Cells. For both transient and stably transfected LNCaP cells, a variety of androgens and anti-androgens -- methyl trienolone (R1881, DuPont NEN), dihydrotestosterone (DHT, Sigma), cyproterone acetate (CA and hydroxyflutamide (Ho-Flu)-- were used to induce expression of the luciferase reporter gene. Androgens or anti-androgens were prepared at 3x concentrations in 10% strip-serum RPMI and added as 50 μL aliquots to each well of the 96-well plate. Cells were incubated with either androgens or anti-androgens for 48 hours before assaying. Assays were done in triplicate or quadruplicate. The concentration of dihydrotestosterone (DHT) was measured by the Testosterone ELISA Kit (Neogen Corporation). The assay has 100% cross reactivity with DHT.

In the case of stably transfected PSE-Luc/LNCaP clones, media was removed and cells washed with PBS (2 x 20 mL). The clonal cells were then maintained in 10% strip-serum RPMI (phenol red free) for 24 hours prior to trypsinizing and replating into an opaque 96-well plate - 40,000 cells/well per 100 μL media. Cells were allowed to become adherent overnight before the addition of either androgens or anti-androgens. Incubation of clonal cells in strip-serum RPMI prior to induction with drug(s) substantially lowered background luciferase expression.

The luciferase assay of both transient and stably transfected cells was performed in the same manner. After induction of cells with androgens or anti-androgens for 48 hours, media was removed and 50 µL of lysis reagent added (0.1 M potassium phosphate buffer at pH 7.8, 1% Triton X-100, 1 mM dithiothreitol, 2mM EDTA) to each well. Cells were assayed within 15 minutes of lysis or stored at -80°C until analysis. Storage of cell lysates at -80°C for five days or less did not result in significant loss of luciferase activity.

The Enhanced Luciferase Assay Kit (Analytical Luminescence Laboratory, MI) was used to quantitate the extent of luciferase activity from PSE-Luc transfected LNCaP cells. A Dynatech 3000 96-well plate luminometer (Dynatech, VA) was used to measure the amount of light generated from the assay. The instrument was run in the Enhanced Flash Mode, employing a dual injector system for substrate addition. Optimal assay conditions and Luminometer parameters were as follows: addition of 60 µL of Substrate A (buffer), 1 second delay, addition of 60 µL of Substrate B (luciferin reagent), 1 second delay, integrate signal for 3 seconds. The results are depicted as the integral sum in relative light units (RLUs). The extent of induction by androgens/anti-androgens, e.g. fold induction, was determined by: *fold induction = RLUs [x nM drug]/RLUs [0 nM drug].*

CMV-Luc/LNCaP Cell Line. Transfections of the control plasmid, CMV-Luc, into LNCaP cells were done in the same fashion as for PSE-Luc. The stable cell line CN1006, containing CMV-Luc, was obtained by selection with G418. The luciferase assay was performed as described above.

Results

Transient Transfections of LNCaP Cells with PSE-Luc. The effectiveness of utilizing PSE-Luc in transient transfections as a transcription screening assay for agonist/antagonist type molecules was examined in LNCaP cells. This transcription assay was evaluated for its use in a 96-well format. The androgens, methyl trienolone (R1881) and dihydrotestosterone (DHT), were used to induce different degrees of luciferase expression under the control of the prostate-specific enhancer.

The inducibility of PSE-Luc by the synthetic androgen R1881 in transiently transfected LNCaP cells was determined. Cells were plated into an opaque 96-well plate at a cell density of 4 x 10^4 cells/well per 100 µL, followed by 50 µL of a 3x media solution containing either R1881 or DHT. Cells were incubated for 48 hours, lysed and assayed for luciferase expression. The extent of induction was determined by dividing the amount of luciferase expression (RLUs) at X nM hormone by the amount of expression without hormone. At 0 nM R1881, luciferase expression in transfected LNCaP cells was similar to background levels (approximately 1-5 RLUs). The addition of 1-50 nM R1881 resulted in an approximately 275 fold induction of luciferase expression (3,000-3,500 RLUs) over uninduced transfected cells. Peak levels of luciferase expression were obtained at 1 nM R1881, which closely corresponds to physiological levels of androgen. Variations in the amount of DNA/Lipid complexes used in transient transfections resulted in comparable results, however lower DNA concentrations (e.g. 1 and 2 µg DNA) gave smaller RLU values after induction. Lastly, %CV varied ranging from 10-30%.

A second androgen, dihydrotestosterone (DHT), was evaluated for its inducibility of transiently transfected LNCaP cells. DHT is a naturally occurring human androgen and the reductive analog of testosterone. The extent of fold induction increased with increasing concentration of DHT. Peak levels of approximately 100 fold were obtained over the background value of 25 RLUs for DHT concentrations of 100 and 200 nM (e.g. 2,500-3,000 RLUs). A comparison of R1881 and DHT shows that approximately 100 fold more DHT is required relative to R1881 to obtain comparable luciferase activity. The difference in fold induction between the two androgens, e.g. 100 vs. 250 fold induction, can be explained by a 2 fold higher background signal for the DHT (12 vs. 25 RLUs), which likely resulted from the particular experimental procedures employed. However, the overall peak expression levels stimulated by the two androgens are comparable. The higher concentration of DHT required to achieve the same luciferase expression levels obtained with R1881 is addressed later.

Androgen and Anti-androgen Responsiveness of Stably Transfected PSE-Luc/LNCaP Cell Line. LNCaP cells were co-transfected with PSE-Luc and pcDNA3 containing the neomycin gene. LNCaP clones containing both genes were selected with G418 and examined

for luciferase expression after induction with either androgen or anti-androgens. As in the case of transient transfections with PSE-Luc, the assay is evaluated in the 96-well format for high throughput screening (HTS) of potential agonist/antagonist.

The hormones R1881 and DHT were utilized to screen for androgen-responsive LNCaP clones containing the PSE-Luc genes. Two clones, designated CN1010 and CN1013, exhibited luciferase activity upon incubation in 1nM R1881 and were characterized further with varying concentrations of R1881 and DHT. The androgen-responsiveness profile of CN1013 is similar to that obtained for transient transfections. Peak values of R1881 induction were obtained at physiological levels (0.1 - 1 nM), while DHT required 100-200 fold greater amounts for comparable expression. The EC_{50} of R1881 in CN1013 was 0.075nM.

The luciferase responsiveness of CN1013 to anti-androgens, hydroxyflutamide (HO-Flu) and cyproterone acetate (Cypro. A), as well as their antagonist behavior to R1881 (1 nM) induced cells was evaluated. Incubation of CN1013 with either anti-androgen resulted in luciferase expression levels similar to that obtained for R1881, but only at elevated concentrations of 100-1,000 fold higher (Figures 1A and 1B): zero or minimal expression was observed at physiological concentrations. The anti-androgens ability to inhibit luciferase expression after induction with 1 nM R1881 is also shown in Figure 1. At all anti-androgen concentrations examined, there was neither inhibition nor induction of luciferase expression after R1881 had been added. The addition of other non-steroidal intracellular receptor ligands unrelated to the androgen receptor, i.e. retinoic acid (RA), did not result in either induction or inhibition of CN1013.

The intra-assay %CVs of the stable cell line CN1013 typically varied between 5-10%. While the initial characterization of CN1013 resulted in %CV slightly higher than 10%, later experiments were able to lower the intra-assay %CV to an acceptable range (Figures 1A and 1B). Transient transfection assays yielded %CVs of 10-30%, whereas stable cell line assays (CN1013), yielded %CVs of 5-10%.

Metabolism of Dihydrotestosterone (DHT) in CN1013 Cell Line. The higher levels of DHT needed to induce luciferase expression in either CN1013 or transient transfections was investigated. The decrease of DHT concentration in CN1013 cells was measured kinetically

utilizing the Testosterone ELISA Kit by Neogen Corporation (100% cross reactivity with DHT). The metabolism of DHT occurs rapidly within 1-4 hours of addition to CN1013 cells, while the DHT concentration remained constant when unexposed to CN1013 cells. The half life of 10 nM DHT in CN1013 cells was calculated to be approximately 1.1 hours. The metabolized product was not identified.

While the overall luciferase expression levels between transient transfections and CN1013 are similar (3000-4000 RLUs), the extent of fold induction upon androgen addition is approximately 5-10 times lower in the latter case due to significant background signal (e.g. 100-200 RLUs). The larger background signal is a result of the requirement of growing CN1013 in hormone containing RPMI. Incubation of CN1013 in 10% strip-serum RPMI (minus hormone) prior to plating into 96-well plates lowered background signal moderately. Further decreases in overall luciferase expression were observed with passage number of the cell line. A comparison of the RLUs at passage 5 and 15 showed an approximate 3-5 fold decrease in luciferase expression, however the overall level of induction remained identical.

The decrease in luciferase expression of CN1013 with increasing passage number resulted in the need to select subclones having enhanced expression levels. Subclones of PSE-Lue/LNCaP were obtained from the parental cell line CN1013 by limiting dilution. Screening of these clones produced a single active clone, designated CN1013.7, which was 5-10 times more active than the parental cell line yielding 100-200 fold induction with R1881.

Luciferase Expression of CMV-Luc/LNCaP Stable Cell Line. LNCaP clones containing the CMV-Luc gene were screened for stable expression of the luciferase gene (i.e. selection of stable cell line). A 3-4 fold increase in expression levels over the uninduced cells was observed upon the addition of 10-1000 nM androgen. A similar androgen stimulation of CMV-Luc expression in transient transfection of LNCaP cells was reported by Pang et al., Hum. Gene Ther. (1995) 6:1417-1426. The slight increase in expression levels was attributed to cell proliferation resulting from increased R1881 addition.

EXAMPLE 2

Construction of reporter constructs in which expression of reporter genes is under the control of the hKLK2 5'-flanking region

To assess the function of the DNA segment containing the enhancer, a series of constructs was generated by inserting the *hKLK2* 5'-flanking region, shown schematically in Figure 2, upstream of the luciferase reporter gene. The activity of these fragments was compared with that of CN299, a plasmid with the full *hKLK2* promoter (-605 to +33) driving the expression of firefly luciferase. The constructs are as follows:

- To clone the *hKLK2* full promoter an approximately 600 bp fragment was amplified with the oligonucleotides 41.100.1 and 42.100.2 (5'-GAT CAC CGG TGC TCA CGC CTG TAA TCT CAT CAC-3' (SEQ ID NO:2), PinAI site underlined). 42.100.2 corresponds to the upstream region of the *hKLK2* promoter. The PCR product was then cloned into pGEM-T vector (Promega) to generate CN294.

- CN299 is a plasmid containing the luciferase coding segment driven by the full *hKLK2* promoter. The full promoter region was released from CN294 by NcoI-SacI digestion and ligated into a similarly cut pGL3-Basic (Promega) to generate CN299.

- CN322 is a plasmid containing the entire structural gene of firefly luciferase driven by the human *hKLK2* promoter and the other all regulatory elements. The entire 12 kbps *hKLK2* 5'-flanking region was excised from CN312 by SacII/SpeI digestion and ligated into SacII/SpeI digested pGL3-Basic to produce CN322.

- CN324 is a luciferase construct containing the *hKLK2* minimal promoter driving the luciferase coding region. The minimal *hKLK2* promoter was released from CN317 by NcoI-SacI digestion and ligated into a similarly cut pGL3-Basic to generate CN324.

- CN325 is the same as CN324, except that a XhoI site (instead of a PinAI site) was created at the 5' end of the minimal promoter.

- CN355 was created by digesting CN340 with XhoI and KpnI. The released fragment (~3.8 kbps) was ligated into CN325, upstream of the minimal promoter.

EXAMPLE 3

Effects of the hKLK2 5'-flanking region

To determine the effect of the 12 kbp 5'-flanking sequence on promoter activity, two constructs were created: CN299 and CN322. The *hKLK2* promoter was cloned upstream of the *luc* gene to create CN299, as described in Example 2. The entire 12 kbp sequence upstream of the *hKLK2* gene (including the promoter) was cloned upstream of the *luc* gene to create CN322, as described in Example 2. Each construct was then used to transfect LNCaP cells. The media in half of the dishes was supplemented with 0.5 nM R1881. The cells were harvested 48 hours post transfection and the luciferase activity was measured. Figures 3A and 3B summarize the data and demonstrate that CN322 has higher activity than CN299. At both R1881 concentrations tested, CN322 had higher activity than CN299. At 0 nM, CN322 was 12 fold more active than CN299. At 0.5 nM, CN322 was approximately 36 fold more active than CN299. These data suggest that the 12 kb 5'-flanking sequence contains an enhancer and that this enhancer is also androgen responsive.

EXAMPLE 4

Characterization of the hKLK2 enhancer

The results of the previous experiment (Example 3) suggested that the luciferase activity of the putative enhancer found in CN322 responded in an androgen dependent manner. To determine if the *hKLK2* 5'-flanking sequence did indeed contain an androgen responsive element, two experiments were conducted. In the first experiment, LNCaP cells were transfected with CN322, the transformants were incubated in medium containing various concentrations of R1881, and 48 hours after transfection, luciferase activity was measured. The results are summarized in Figures 4A and 4B. In short, CN322 responded to the

testosterone analog R1881 in a concentration dependent manner. Peak induction of activity was estimated at 1 nM R1881, about 9 fold over the 0 nM activity.

In the second experiment, the effect of time of incubation in the presence of R1881 on the activity of the 12 kb 5'-flanking sequence was assessed. LNCaP cells were transfected with CN322 and incubated for various periods of time in the presence of 0.5 nM R1881 before harvesting. The results are summarized in Figure 5. The peak luciferase activity was seen at 60 hours post transfection, but the overall upward trend seemed to plateau at about 48 hours post transfection.

To summarize these two experiments, it seemed that the *hKLK2* enhancer appears to be androgen responsive and peak induction of *luc* activity takes place somewhere between 48 and 60 hours post transfection.

EXAMPLE 5

Tissue specificity of the hKLK2 enhancer

Knowing that the *PSA* enhancer is tissue specific, a series of experiments was conducted to determine if the same was true for the *hKLK2* enhancer. In the first experiment, LNCaP cells (a PSA-producing prostate cancer cell line) and 293s (a human embryonic kidney cell line) were transfected with CN299 or CN322 (Example 2). Half of the dishes were supplemented with 1 nM R1881, and the cells were harvested 48 hours post transfection. The LNCaP cells transfected with CN322 exhibited a 17 fold induction of activity in the presence of 1 nM R1881 when compared to the background activity at 0 nM R1881. The 293s transfected with CN322 showed a reduction of luciferase activity in the presence of 1 nM R1881. CN299 exhibited a 2-3 fold induction in the presence of 1 nM R1881, and a reduction of activity in the 293 cells. The results of this first experiment are summarized in Figure 6. The results of this experiment again support the conclusion that the *hKLK2* enhancer is androgen inducible.

Results of earlier experiments indicated that a putative *hKLK2* enhancer may lie between the ApaI site at approximately -6200 bp and the XhoI site at approximately -2400 bp of the *hKLK2* enhancer. This 3.8 kbp fragment was fused upstream of the minimal *hKLK2*

promoter and then cloned upstream of the *luc* gene, creating CN355. A variety of cell lines were transfected with CN322 or CN355 by incubating them with the complexes in complete media overnight. The complexes were then aspirated and the media was replaced with stripped serum media. The media in half of the plates was supplemented with 1 nM R1881. The cells were then harvested 48 hours after the removal of the DNA-lipid complexes and tested for luciferase activity. The results are summarized in Figure 7.

CN322 gave almost a 100 fold induction of activity in the presence of 1 nM R1881 in the LNCaP cells. CN355 exhibited a 35-fold induction of activity under the same conditions. All of the other cell lines, including the prostate-derived cell line PC3, showed little androgen inducibility. In fact, CN322 and CN355 showed only about a 1-2 fold induction in any of the other cell lines. Although the PC3 cell line is prostate derived, it lacks an androgen receptor. To further delineate the sequences required for enhancer activity, the construct CN379 was made, which has, in addition to a minimal *hKLK2* promoter, the region from -5155 to -3412 driving expression of the luciferase gene. Using the same assay methods described above, this construct gave approximately 54-fold induction of luciferase activity in the presence of inducing agent R1881.

These data show that the minimal enhancer constructs CN355 and CN379 retained some of the activity of the full 12 kbps 5'-flanking sequence, indicating that part of the putative *hKLK2* enhancer is between the ApaI and XhoI sites previously described above. The data also support the conclusion that the *hKLK2* enhancer is androgen responsive and that its activity is restricted to cell lines containing an androgen receptor.

It is evident from the above results that simple and rapid screening methods are provided for determining activity of compounds in inhibiting proliferation of prostate cancer. The methods employ cells which are stable, can be easily grown, and can be used in a conventional format to identify the activity of specific compounds. The results are at least semi-quantitative, and allow for high throughput screening with automated equipment.

All publications and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

The invention now being fully described, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the appended claims.

SEQUENCE LISTING

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(ii) TITLE OF THE INVENTION: PROSTATE CANCER DRUG SCRE
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(v) COMPUTER READABLE FORM:
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(B) COMPUTER: IBM Compatible
(C) OPERATING SYSTEM: DOS
(D) SOFTWARE: FastSEQ for Windows Version 2.0

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(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 12047 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

GAATTCAGAA ATAGGGGAAG GTTGAGGAAG GACACTGAAC TCAAAGGGGA TACAGTGATT 60
GGTTTATTTG TCTTCTCTTC ACAACATTGG TGCTGGAGGA ATTCCCACCC TGAGGTTATG 120
AAGATGTCTG AACACCCAAC ACATAGCACT GGAGATATGA GCTCGACAAG AGTTTCTCAG 180
CCACAGAGAT TCACAGCCTA GGGCAGGAGG ACACTGTACG CCAGGCAGAA TGACATGGGA 240
ATTGCGCTCA CGATTGGCTT GAAGAAGCAA GGACTGTGGG AGGTGGGCTT TGTAGTAACA 300
AGAGGGCAGG GTGAACTCTG ATTCCCATGG GGGAATGTGA TGGTCCTGTT ACAAATTTTT 360
CAAGCTGGCA GGGAATAAAA CCCATTACGG TGAGGACCTG TGGAGGGCGG CTGCCCCAAC 420
TGATAAAGGA AATAGCCAGG TGGGGGCCTT TCCCATTGTA GGGGGGACAT ATCTGGCAAT 480
AGAAGCCTTT GAGACCCTTT AGGGTACAAG TACTGAGGCA GCAAATAAAA TGAAATCTTA 540
TTTTTCAACT TTATACTGCA TGGGTGTGAA GATATATTTG TTTCTGTACA GGGGGTGAGG 600
GAAAGGAGGG GAGGAGGAAA GTTCCTGCAG GTCTGGTTTG GTCTTGTGAT CCAGGGGGTC 660
TTGGAACTAT TTAAATTAAA TTAAATTAAA ACAAGCGACT GTTTTAAATT AAATTAAATT 720
AAATTAAATT TTACTTTATT TTATCTTAAG TTCTGGGCTA CATGTGCAGG ACGTGCAGCT 780
TTGTTACATA GGTAAACGTG TGCCATGGTG GTTTGCTGTA CCTATCAACC CATCACCTAG 840
GTATTAAGCC CAGCATGCAT TAGCTGTTTT TCCTGACGCT CTCCCTCTCC CTGACTCCCA 900
CAACAGGCCC CAGTGTGTGT TGTTCCCCTC CCTGTGTCCA TGTGTTCTCA TTGTTCAGCT 960
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(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 33 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

GATCACCGGT GCTCACGCCT GTAATCTCAT CAC 33

CLAIMS

What is claimed is:

1. A method for screening drugs for the treatment of prostate cancer employing PSA expressing cells comprising an expression construct which comprises a transcriptional initiation region of the prostate specific antigen enhancer and a promoter and a gene whose expression product provides a detectable signal, wherein said gene is under the transcriptional control of said transcriptional initiation region, said method comprising;

combining said PSA expressing cells with a candidate drug in the presence of an androgen for sufficient time for detectable expression of said gene; and

detecting the level of expression of said gene as compared to the level of expression in the absence of said candidate drug.

2. A method according to Claim 1, wherein said gene expresses an enzyme.

3. A method according to Claim 2, wherein said enzyme is luciferase.

4. A method according to Claim 3, wherein said detecting comprises:

lysing said PSA expressing cells; and

assaying said lysate for luminescence.

5. A method according to Claim 1, wherein said androgen is methyl trienolone or dihydrotestosterone.

6. A method for screening drugs for the treatment of prostate cancer employing PSA expressing cells comprising an expression construct which comprises a transcriptional initiation region of the prostate specific antigen enhancer and a promoter and a gene encoding an enzyme which catalyzes a reaction resulting, in a detectable signal, wherein said gene is under the transcriptional control of said transcriptional initiation region, said method comprising;

combining said PSA expressing cells with a candidate drug in the presence of methyl trienolone or dihydrotestosterone for sufficient time for detectable expression of said enzyme;

lysing said PSA expressing cells to provide a lysate and adding the substrate of said enzyme to said lysate; and

detecting the level of expression of said enzyme as compared to the level of expression in the absence of said candidate drug.

7. A method according to Claim 6, wherein said PSA expressing cells are LNCaP cells and said enzyme is luciferase.

8. A method for screening compounds for the treatment of prostate cancer employing mammalian cells comprising an expression construct, said expression construct comprising an enhancer of a prostate-specific gene and a promoter and a reporter gene whose expression product provides a detectable signal, wherein said reporter gene is under the transcriptional control of said enhancer, said method comprising the steps of:

a) combining said cells with a candidate compound for a sufficient time for detectable expression of said reporter gene; and

b) detecting the level of expression of said reporter gene as compared to the level of expression in the absence of said candidate compound.

9. A method according to claim 8, wherein said reporter gene expresses an enzyme.

10. A method according to claim 9, wherein said enzyme is luciferase.

11. A method according to claim 10, wherein said detecting comprises:
lysing said mammalian cells; and assaying said lysate for luminescence.

12. A method according to claim 8, wherein said enhancer is an enhancer region of the human prostate specific antigen gene.

13. A method according to claim 8, wherein said enhancer is an enhancer region of the human glandular kallikrein (*hKLK2*) gene.

14. The method according to claim 13, wherein the *hKLK2* enhancer encompasses nucleotides 1 to 9765 of SEQ ID NO:1 or active fragments thereof.

15. The method according to claim 13, wherein the *hKLK2* enhancer encompasses nucleotides 5976 to 9620 of SEQ ID NO:1 or active fragments thereof.

16. The method according to claim 13, wherein the *hKLK2* enhancer encompasses nucleotides 6859 to 8627 of SEQ ID NO:1 or active fragments thereof.

17. The method according to claim 13, wherein the mammalian cells are prostate cells containing an endogenous androgen receptor.

18. The method according to claim 13, wherein the enhancer is an *hKLK2* enhancer and the promoter is an *hKLK2* promoter.

AMENDED CLAIMS

[received by the International Bureau on 14 March 1998 (14.03.98); original claims 8-18 amended; new claims 19-25 added; remaining claims unchanged (3 pages)]

combining said PSA expressing cells with a candidate drug in the presence of methyl trienolone or dihydrotestosterone for sufficient time for detectable expression of said enzyme;

lysing said PSA expressing cells to provide a lysate and adding the substrate of said enzyme to said lysate; and

detecting the level of expression of said enzyme as compared to the level of expression in the absence of said candidate drug.

7. A method according to Claim 6, wherein said PSA expressing cells are LNCaP cells and said enzyme is luciferase.

8. A method according to claims 1 or 6, wherein the prostate specific antigen enhancer comprises a sequence encompassing nucleotides between about -5824 to about -3738 of the upstream region of the PSA gene, wherein the enhancer exhibits enhancer activity.

9. A method according to claims 1 or 6, wherein the prostate specific antigen enhancer is contained within a polynucleotide fragment of about 5.8 kilobases from about -5824 to about +1 of the upstream region of the PSA gene, wherein the enhancer exhibits enhancer activity.

10. A method according to claim 10, wherein the promoter comprises a sequence encompassing nucleotides between about -560 to about +7 of the PSA gene.

11. A method for screening compounds for the treatment of prostate cancer employing cells comprising an expression construct, said expression construct comprising an enhancer of a prostate-specific gene and a promoter and a reporter gene whose expression product provides a detectable signal, wherein said reporter gene is under the transcriptional control of said enhancer, said method comprising the steps of:

a) combining said cells with a candidate compound for a sufficient time for detectable expression of said reporter gene; and

b) detecting the level of expression of said reporter gene as compared to the level of expression in the absence of said candidate compound.

12. A method according to claim 11, wherein said reporter gene expresses an enzyme.

13. A method according to claim 12, wherein said enzyme is luciferase.

14. A method according to claim 13, wherein said detecting comprises: lysing said cells; and assaying said lysate for luminescence.

15. A method according to claim 11, wherein said enhancer is an enhancer region of the human prostate specific antigen (PSA) gene.

16. A method according to claim 15, wherein the prostate specific antigen enhancer comprises a sequence encompassing nucleotides between about -5824 to about -3738 of the upstream region of the PSA gene, wherein the enhancer exhibits enhancer activity.

17. A method according to claim 11, wherein said enhancer from the human glandular kallikrein (*hKLK2*) gene.

18. A method according to claim 17, wherein the *hKLK2* enhancer comprises a sequence encompassing nucleotides about 1 to about 9765 of SEQ ID NO:1 or active fragments thereof.

19. A method according to claim 17, wherein the *hKLK2* enhancer comprises a sequence encompassing nucleotides about 5976 to about 9620 of SEQ ID NO:1 or active fragments thereof.

20. A method according to claim 17, wherein the *hKLK2* enhancer comprises a sequence encompassing nucleotides about 6859 to about 8627 of SEQ ID NO:1 or active fragments thereof.

21. A method of any of claims 17 to 20, wherein the promoter is an *hKLK2* promoter.

22. A method of any of claims 11 to 21, wherein the cells are mammalian.

23. A method of claim 22, wherein the mammalian cells express prostate specific antigen.

24. A method of claim 22 or 23, wherein the cells are prostate.

25. A method of claim 24, wherein the prostate cells contain an endogenous androgen receptor.

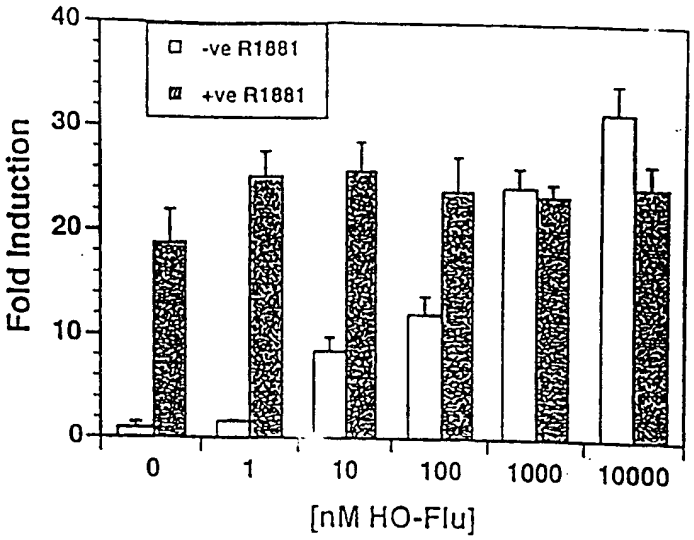

Figure 1 A

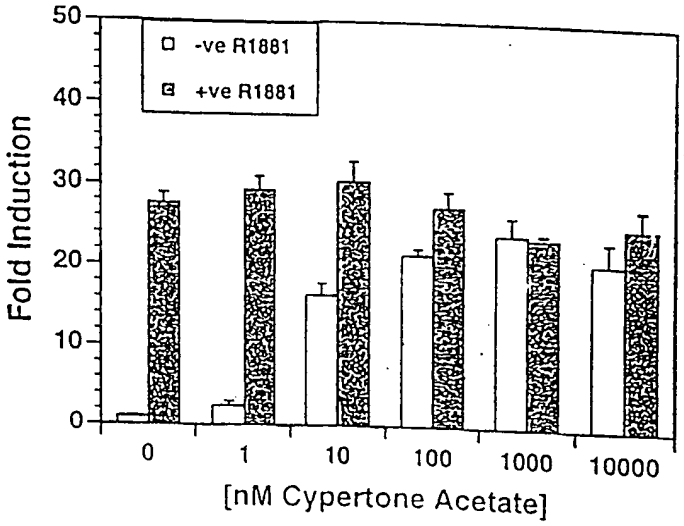

Figure 1 B

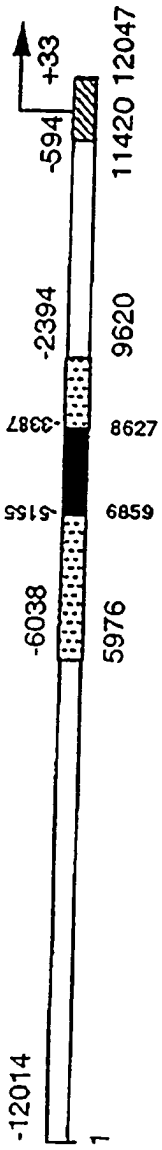

Figure 2

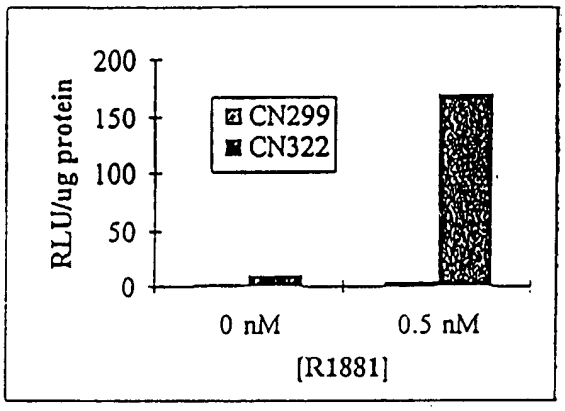

Figure 3 A

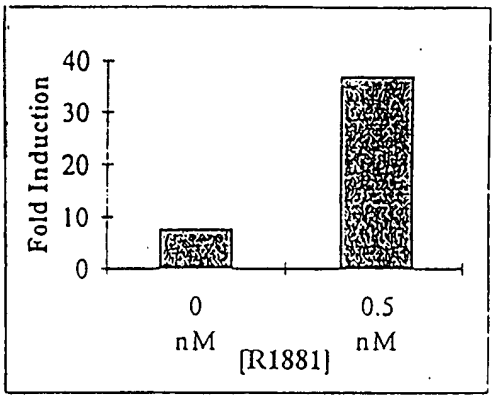

Figure 3 B

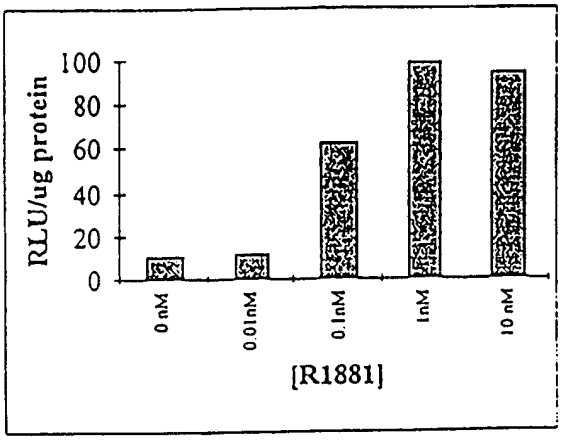

Figure 4 A

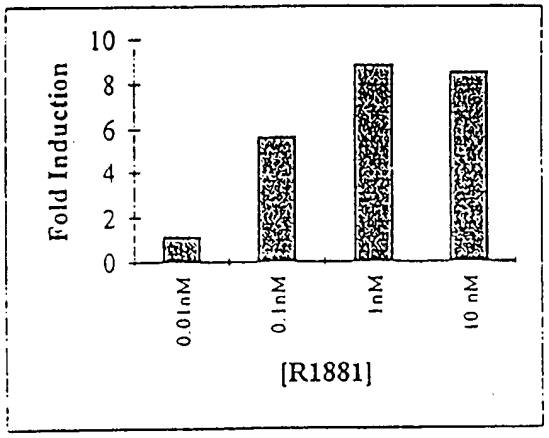

Figure 4 B

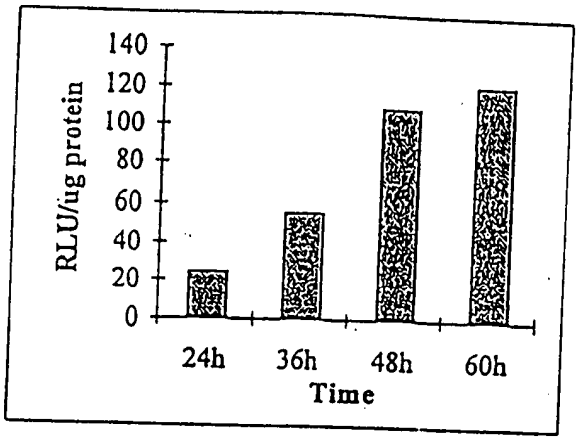

Figure 5

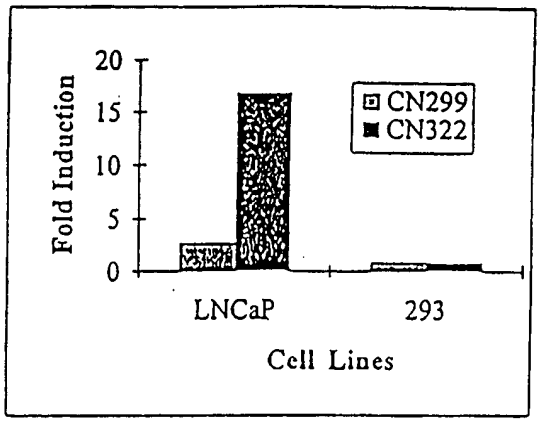

Figure 6

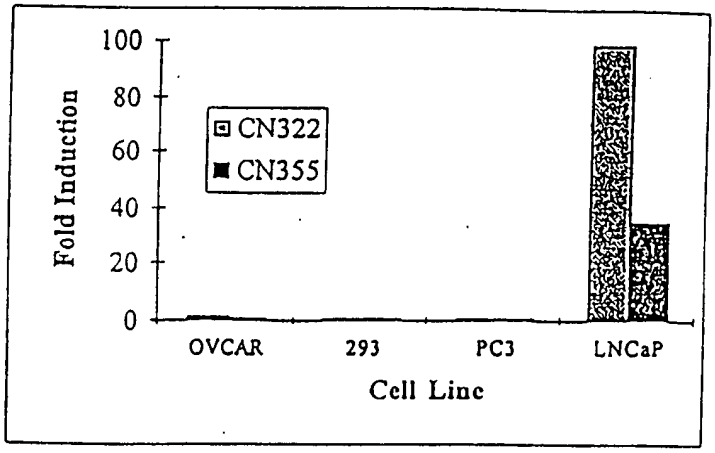

Figure 7

INTERNATIONAL SEARCH REPORT

Inter[illegible]al Application No
PC[illegible]S 97/13888

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C12Q1/68 G01N33/574

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C12Q

Documentation searched other than minimumdocumentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SCHUUR E R ET AL: "Prostate -specific antigen expression is regulated by an upstream enhancer." JOURNAL OF BIOLOGICAL CHEMISTRY (MICROFILMS), vol. 271, no. 12, March 1996, MD US, pages 7043-7051, XP002050776 see the whole document specially see page 7044, right-hand column, last paragraph; figure 1 --- -/--	1-12

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publicationdate of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of theinternational search	Date of mailing of the international search report
19 December 1997	15/01/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Molina Galan, E

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INTERNATIONAL SEARCH REPORT

Inte[illegible]al Application No
PCT/US 97/13888

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication where appropriate of the relevant passages	Relevant to claim No.
Y	MURTHA P ET AL: "ANDROGEN INDUCTION OF A HUMAN PROSTATE-SPECIFIC KALLIKREIN HKLK2 CHARACTERIZATION OF AN ANDROGEN RESPONSE ELEMENT IN THE 5' PROMOTER REGION OF THE GENE." BIOCHEMISTRY 32 (25). 1993. 6459-6464. CODEN: BICHAW ISSN: 0006-2960, XP002050777 cited in the application see the whole document	13-18
Y	WO 95 06754 A (UNIV CALIFORNIA) 9 March 1995 see the whole document	1-18
A	WO 95 19434 A (CALYDON INC) 20 July 1995	
A	WILLIAMS T M ET AL: "ADVANTAGES OF IREFLY LUCIFERASE AS A REPORTER GENE: APPLICATION TO THE INTERLEUKIN-2 GENE PROMOTER" ANALYTICAL BIOCHEMISTRY, vol. 176, no. 1, January 1989, pages 28-32, XP000601607	
A	YOUNG El Al..: "Tissue-specific and hormonal regualtion of human prostate-specific glandular kallikrein" BIOCHEMISTRY, vol. 31, 1992, EASTON, PA US, pages 818-824, XP002050778 cited in the application	

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INTERNATIONAL SEARCH REPORT

...on on patent family members

Inte...al Application No
PC... 97/13888

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		AU 7719094 A	22-03-95
		CA 2169466 A	09-03-95
		EP 0724648 A	07-08-96
		JP 9502345 T	11-03-97
		NO 960715 A	22-02-96
WO 9519434 A	20-07-95	AU 1686995 A	01-08-95
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